CETEX
Centre for Economic Transition Expertise
Research and Policy at LSE

THE CETEX DISCUSSION PAPER SERIES: LAND AND OCEAN

Exploring the interactions between nature loss drivers, vulnerabilities and economic impacts

Elena Almeida, Chiara Colesanti Senni and Jelica Rastoka

Summary

Nature loss presents significant economic and financial risks by disrupting the ecosystem services essential for economic stability and societal wellbeing. Its impacts vary widely across regions and sectors, often exacerbated by vulnerabilities such as supply chain interdependencies and resource dependence.

We analyse 14 case studies to understand recurring patterns from historical nature loss events and create insights for developing proactive and integrated strategies to address these multifaceted challenges. Incidences of olive tree disease, harmful algal blooms and cod species demise stand out in particular for the diverse and ongoing challenges they present. These examples underscore how the same drivers can yield vastly different macroeconomic outcomes depending on the vulnerabilities present.

Nature loss reduces total factor productivity, a fundamental driver of GDP growth, while also disrupting labour dynamics and population growth. Weak institutions, limited economic diversification, and overdependence on natural resources amplify these effects, creating cascading risks. The heterogeneity of nature loss impacts, both regionally and across agents, complicates economic recovery and risk management.

To address these challenges, we recommend: 1) adopting advanced multi-agent economic models to better capture the heterogeneity of impacts; 2) implementing targeted financial and fiscal interventions to enhance resilience; 3) strengthening prudential regulation to manage nature-related financial risks; and 4) integrating ecosystem services into risk assessments and economic planning to anticipate and mitigate potential crises.

Policy Briefing **Paper 3**

30 January 2025

The CETEx Discussion Paper Series: Land and Ocean is designed to provide a broader and deeper understanding of environmental risks by introducing economic and financial policymakers to ecosystem degradation issues such as deforestation, pollution and biodiversity loss on land and in the oceans. The series aims to support financial and economic policymakers as they contend with and make considerations for these environmental degradation issues, in addition to climate change. The papers have been written and peer-reviewed by leading experts from academia, think tanks and central banks and are based on cutting-edge research.

LSE The London School of Economics and Political Science

Grantham Research Institute on Climate Change and the Environment

1. Introduction

Through an in-depth exploration of dimensions from labour supply dynamics to supply chain vulnerabilities, in this paper we explore the multifaceted impacts of nature loss on economies worldwide. Nature loss poses significant economic and financial risks, disrupting the ecosystem services essential to economies and societies. Its impacts vary by region and sector and are amplified by vulnerabilities such as supply chain connections and resource dependence. Understanding repeated patterns from historical nature loss events can support the development of nuanced, forward-looking strategies to address these complex, interconnected risks.

Economic and financial policymakers have acknowledged that nature degradation and biodiversity loss, and their increased frequency, can significantly affect financial and macroeconomic stability. Efforts have been undertaken to improve understanding of environmental risk beyond climate change, particularly that deriving from the degradation of ecosystem services.

While natural, human and physical capital are intrinsically related in their support of human welfare, there has been a remarkable record of disparity in their evolution. Between 1992 and 2014, the amount of natural capital per person shrunk by 40%, while produced and human capital increased by as much as 13% (Dasgupta, 2021). Apart from environmental sustainability concerns, this divergence raises questions about economic viability. Soil erosion, for instance, has caused significant nutrient loss from agricultural soils, with annual replacement costs for nitrogen and phosphorus estimated at US$33–60 billion and US$77–140 billion, respectively (FAO and ITPS, 2015). These rising costs place financial strain on businesses, limiting their ability to invest in sustainable practices such as crop diversification. Another striking finding is that over 70% of emerging infectious diseases stem from animals, and that incubation of these diseases is facilitated by ecosystem degradation that disrupts natural disease regulation and resource availability, affecting hygiene and disease control (Espinosa et al., 2020; Everard et al., 2020). These are just a few of the examples of nature loss impacts that are presenting growing economic, financial and social risks, brought to light by research on ecosystem health (Espinosa et al., 2020; NGFS-INSPIRE, 2022).

On a microeconomic scale, disruption to natural resources, such as reduced availability of freshwater, can lead to business losses and destabilise financial systems; for example, CISL and HSBC (2022) project a 25% turnover drop in East Asian steel companies during times of water supply disruption. In macroeconomic terms, ecosystem collapse could potentially reduce global GDP by up to 2.3%, with disproportionate impacts to low-income economies, where losses may reach 10% of GDP (Johnson et al., 2021). This is comparable to the global GDP loss of 2.9% during the financial crisis of 2008 (Inklaar et al., 2018). Moreover, risks stemming from nature loss are compounded by non-linear tipping points, feedback loops and amplification effects, such as rising food prices due to land degradation and the interaction of biodiversity loss with climate change.

Policymakers face the dual challenge of quantifying these risks, which vary by economic structure, and addressing their interconnected nature.

“Ecosystem collapse could potentially reduce global GDP by up to 2.3%, with disproportionate impacts to low-income economies, where losses may reach 10% of GDP.”

Recent studies reveal that a significant portion of financial systems are deeply dependent on ecosystem services, with 75% of euro-area corporate loan exposures vulnerable to nature degradation, for example (Boldrini et al., 2023). Central banks and financial supervisors have begun to recognise the gravity of these risks (Ceglar et al., 2024; Elderson, 2024; World Bank and BNM, 2022), and are investing considerable resources to develop nature scenarios that map out possible future risks (NGFS, 2023). However, the heterogeneity of nature loss events, their local specificity and their complex transmission channels require robust, nuanced approaches to safeguard both global financial stability and environmental sustainability.

The quantification of nature-related risks is challenging due to a variety of factors, including the difficulty of translating biophysical outcomes into economic variables. Importantly, the consequences of nature loss might vary depending on the structure of the economy: for low-and middle-income economies or regions dependent on agriculture or natural resource extraction (e.g. mining, fishing and forestry), impacts of nature loss on the aggregate economy can be significant. For high-income economies that have transitioned to manufacturing- and services-based economies, the direct effects of nature loss might appear to be small (Johnson et al., 2021) but this underestimates important amplification effects, such as supply chain linkages, the climate-nature nexus and heterogeneities in the impacts of nature loss across regions and segments of society.

This briefing paper aims to showcase historical nature loss events, focussing on their drivers, vulnerabilities and transmission channels to improve understanding of nature-related risks and support policymakers to better mitigate these risks. The paper is structured as follows: Section 2 introduces the cases of nature loss events reviewed, which are then detailed in Section 3 along with their macroeconomic implications. Section 4 discusses insights from the case studies in more depth by theme, to help inform better risk management strategies and prompt a more integrated approach to addressing risk. Section 5 concludes with four recommendations for policymakers.

2. Scope and approach

Fourteen cases of nature loss events were studied to examine patterns of interaction between drivers of nature loss, vulnerabilities and their economic impacts, and how these interconnections undermine economic stability, livelihoods and societal wellbeing.

To understand how nature loss events have mattered for the economy and the financial system, we reviewed historical records based on previous literature (Ranger et al., 2023) and selected cases that: are well-documented and showcase a link between nature loss and economic outcomes; are relevant to current or future nature loss events; and enable temporal and regional comparisons. We conducted semi-structured interviews with experts to affirm that the cases selected were relevant and informative. We then cross-referenced with suggestions from ChatGPT. This led to the selection of 14 cases for review (see Table 1). In the remainder of the paper, case names are italicised and refer to those listed in Table 1. Our observations and conclusions are informed by the cases selected and interview responses and are by no means exhaustive.

“The heterogeneity of nature loss events, their local specificity and their complex transmission channels require robust, nuanced approaches to safeguard global financial stability and environmental sustainability.”

Table 1. Nature loss case studies considered in this paper

Case name	Summary	Location	Decades of occurrence
Potato crop disease	Potato blight caused by a fungus which caused potato rotting, making the harvest inedible.	Ireland	Mid 1840s-1850s
Olive tree disease	Bacterial disease (*Xylella Fastidiosa*) resulted in widespread tree destruction. Trees were destroyed due to disease and more were cut down to prevent the spread of the bacteria.	Mediterranean (mainly Italy)	Ongoing since the 2010s
Soil loss	Factors including land use change and overexploitation led to declining soil quality and agricultural yields.	Malawi	Ongoing since the 1990s
Mountain pine beetle invasion	Warmer winters due to climate change caused mountain beetles to survive long enough to reproduce, leading to an increasing population, which become destructive for pine trees. Trees were destroyed by the beetle and more were cut down to prevent further spread.	British Columbia, Canada	1990s-2000s
Banana plant disease	Disease caused by a soil pathogen (*fusarium wilt*) that causes banana trees to become stunted and eventually die. Plants had to be destroyed to prevent the spread and farms were taken out.	Pan-tropical: Australia, China, Indonesia, Malaysia, Mozambique, Philippines and Taiwan	1950s, 1990s and current
Dust Bowl	Prolonged and severe dust storms that caused droughts and destroyed agricultural land.	Texas and Oklahoma, United States	1930s
Demise of cod species	Irreversible demise of cod caused by overfishing and worsened by changing ecosystem conditions.	Newfoundland and Labrador, Canada	1990s
Harmful algal blooms	The development of blooms caused by eutrophication, resulting in the production of toxic compounds that contaminate seafood and drinking water, while depleting oxygen and creating death zones.	California, United States and Lake Erie, Canada	Ongoing; severe cases since the 1980s
COVID-19 outbreak	Highly contagious respiratory zoonotic disease affecting humans and resulting in sickness and death.	Global	2020s
Prolonged droughts	Prolonged droughts due to climate change, causing multiple crop failure.	Middle East and global	2010s
Demise of vulture species	Vulture extinction caused by poisoning from eating carrion of cattle that was treated with a medicine intended for humans.	India and Spain	1990s (India); 2020s (Spain)
Grapevine disease	Fungal disease (powdery mildew) that reduced the yield and quality of grapes.	Global but particularly Australia	Ongoing since the 2010s
Aral Sea degradation	The shrinking of the Sea (an inland lake) caused by the diversion of rivers that supplied it with water, and the resultant degradation of the Sea's ecosystem.	Central Asia, between Kazakhstan and Uzbekistan	1960s-2010s
Ebola outbreak	Highly contagious zoonotic disease affecting humans and resulting in sickness and death.	West Africa, particularly Sierra Leone, Liberia and Guinea	2010s

Based on the review of cases, we identified patterns of the interactions between nature loss drivers, vulnerabilities and transmission channels to the economy to map out how nature loss can affect the economy and diminish societal wellbeing.

Drivers are direct or indirect processes that lead to nature loss. We associate each case with five main drivers of nature loss drawing on categories identified by IPBES (n.d., a), namely: invasive species, land use change, overexploitation, pollution and climate change.

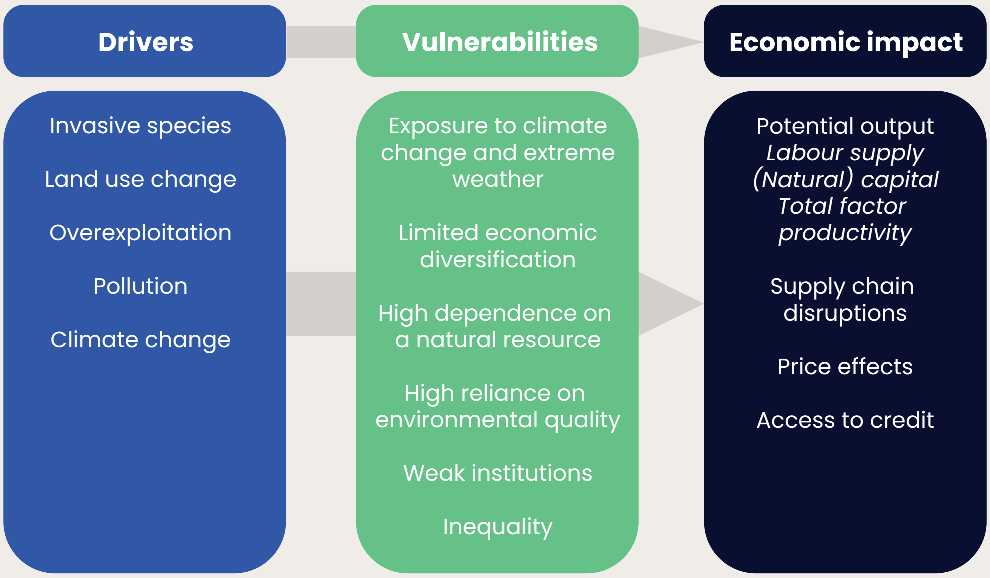
Vulnerabilities amplify the effects of these drivers by influencing the extent, duration and economic transmission of nature loss events. These vulnerabilities exacerbate impacts on ecosystem services like water availability, provision of tourism assets and food, leading to economic losses and greater societal disparities. From our review we identified the following vulnerabilities: exposure to climate change and extreme weather, limited economic diversification, high dependence on a natural resource, high reliance on environmental quality, and weak institutions and income inequality.

Macroeconomic impacts manifest as reduced potential output (due to diminished natural or physical capital, labour supply and productivity) disruptions to supply chains, price fluctuations, and constrained access to credit.

Figure 1 illustrates the framework's interactions. For instance, invasive species and climate change typically combine as drivers of nature loss. The resultant nature loss is amplified by biophysical or economic vulnerabilities such as exposure to climate change, a strong dependency on a specific natural resource and high reliance on environmental quality, with the main transmission to the macroeconomy being through labour. (See the Appendix for a more detailed description of these elements.)

"Vulnerabilities exacerbate impacts on ecosystem services like water availability, provision of tourism assets and food, leading to economic losses and greater societal disparities."

Figure 1. Overview of transmission from nature loss to macroeconomic consequences



3. Review of selected nature loss events

The review of 14 cases (see Table 1) highlights recurring patterns of interactions between nature loss drivers, vulnerabilities and economic impacts. Of particular note is the recurrence of similar drivers, with economic outcomes exacerbated by interactions with multiple vulnerabilities and transmission channels. Cases that share a driver may have diametrically different macroeconomic implications, depending on existing vulnerabilities, suggesting that specific interactions of vulnerabilities and drivers matter to understanding the different ways nature loss events propagate through the economy.

We selected five of the 14 cases (*olive tree disease, harmful algal blooms, demise of cod species, soil loss* and *degradation of the Aral Sea*) that demonstrate the different drivers, vulnerabilities and impact to the economy through varied transmission channels. These five cases were also selected as they are either ongoing or likely to recur due to environmental degradation trends, particularly climate change and the spread of invasive species, and their transmission channels from nature loss to economic impact are historically analogous to other cases (and may be again in the future).

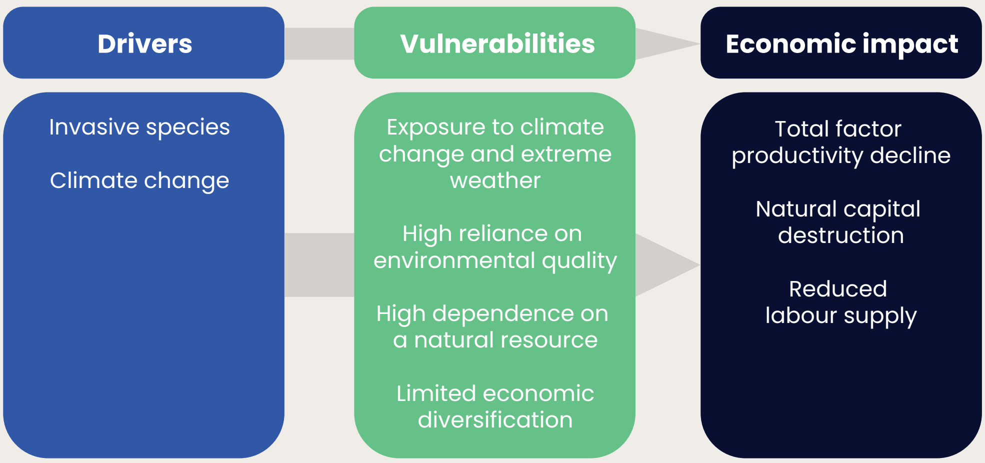
3.1. Olive tree disease in Italy

In the case of *olive tree disease*, nature loss has been driven by the interaction between an invasive bacterial alien species, *Xylella Fastidiosa*, and climate change. Within the Mediterranean region, Italy is particularly affected. The spread and pervasiveness of the bacteria has been exacerbated by climate change and extreme weather (Mainka and Howard, 2010): in the 2010s, warm winters helped the bacteria to thrive (Fraga et al., 2019; Bosso et al., 2016) and spread disease in olive trees (Hopkins and Purcell, 2002), causing substantial loss of olive plantations. The disease is still present in some parts of the Mediterranean today. In addition to trees damaged by the bacteria, the Italian government mandated cutting down healthy trees to prevent the spread of the disease.

The extent of the damage has been enhanced by the interaction of several vulnerability factors that are particularly present in the southern Italian province of Puglia. While the Italian economy is well diversified at the national level, Puglia's regional economy is not, relying

"In the case of olive tree disease, nature loss has been driven by the interaction between an invasive bacterial alien species and climate change."

Figure 2. Olive tree disease: from nature loss to economic impact



on monocultural production of olives (high dependence on a natural resource) and tourism opportunities provided by the picturesque landscapes of olive tree plantations (high reliance on environmental quality). Climate change and extreme weather have affected pathogen development, increasing the area susceptible to outbreaks and facilitating excessive reproduction and the spread of the bacteria.

The *Xylella Fastidiosa* bacteria's devastation of olive production has had severe impacts on the agricultural sector and the broader economy. The destruction of olive trees represents a loss of natural capital, reducing their availability as a factor of production. This has diminished crop yields and lowered fruit quality, leading to a decline in total factor productivity (TFP) and affecting dependent supply chains, such as olive oil production. Additionally, particularly in regions where the labour force is highly specialised in olive cultivation, employment opportunities have been diminished.

3.2. Harmful algal blooms in North America

The case of *harmful algal bloom* development illustrates how the interaction of climate change, weather anomalies and pollution can negatively affect the quality of an ecosystem. Favourable conditions for harmful algal blooms (HABs) were created in several North American locations in the 2010s by increased rainfall and higher water temperatures linked to climate change, combined with chemical pollution and fertilizer runoff (Michalak et al., 2013; Sanseverino et al., 2016). HABs release toxins that are damaging to plants, animals and humans (Hoagland et al., 2002; Adams and Larkin, 2013). Eliminating HABs typically involves the use of copper sulphate, but this is a further source of pollution, associated with fish deaths (Hall et al., 2008).

“The case of harmful algal bloom development illustrates how the interaction of climate change, weather anomalies and pollution can negatively affect the quality of an ecosystem.”

In Florida in the late 2010s, HABs caused a US$45 million decrease in sales and services taxes collected, due to a decline in tourist visits and through spillover effects to service sectors reliant on tourism (Ferreira et al., 2023). Local tourism providers who could not relocate bore the largest burden of this nature loss event (Hoagland et al., 2002; Ferreira et al., 2023). This case emphasises the redistributive effects and heterogeneous impacts that nature loss creates on different economic agents.

The impacts of HABs were transmitted to the economy through output and price effects and were dramatically enhanced by the impacted regions' substantial reliance on environmental quality and spillover effects within and beyond the affected areas. The consumption of seafood from HAB-affected waters caused food poisoning among workers, leading to

Figure 3. Harmful algal blooms: from nature loss to economic impact

fewer hours worked due to absence (decreasing labour supply in terms of average hours worked), and reduced the productivity of sick workers who continued to work (decreasing labour productivity and therefore TFP) (Prasad et al., 2004; Hoagland et al., 2002). News about the seafood-related food poisoning spread, negatively affecting sales of seafood in adjacent areas that were unaffected by HABs, ultimately impacting the price of seafood (Parsons et al., 2006; Jin et al., 2008).

Price effects were also evident for waterfront properties: HAB incidents have been associated with falls in short-term rental revenues (Court et al., 2021; Ferreira et al., 2023) and apparent declines in housing prices (Dodds et al., 2009). A single HAB event does not cause damage sizeable enough to negatively impact aggregate economic performance. However, HAB events are recurring with increasing frequency around the world and their cumlative effects make a strong case for investment in HAB mitigation; such activities have been associated with increases in surrounding property values (Kashian et al., 2006), suggesting that the price effects of HABs could be managed.

3.3. Demise of cod species in Canadian waters

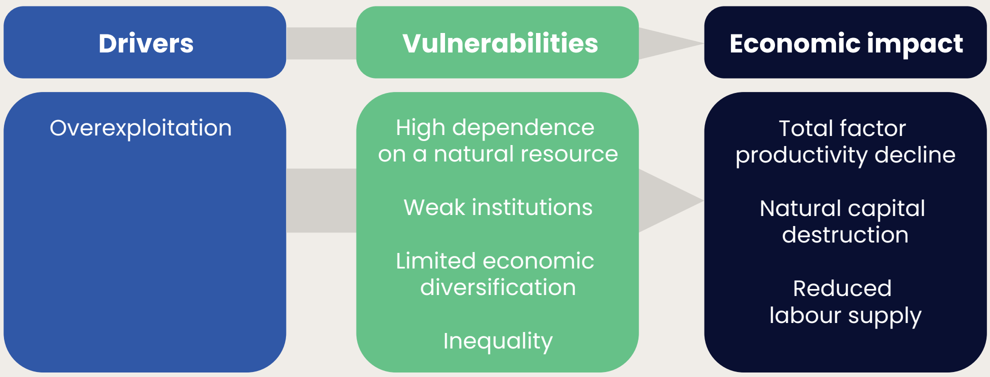
The *demise of cod species* in the North Atlantic waters bordering the eastern Canadian province of Newfoundland and Labrador in the 1990s is an example of irreversible nature collapse, where overexploitation in the form of prolonged overfishing depleted the cod population (Schrank, 2005; Higgins, 2008). The demise of cod fundamentally eroded the foundations of the fishing industry, the dominant economic activity in the province, which was deeply intertwined with the livelihoods and culture of local people.

The high reliance on cod as a natural resource coupled with limited regional economic diversification affected incomes, livelihoods and employment opportunities in Newfoundland. These economic vulnerabilities were further exacerbated by weak institutions, with local governments mismanaging local marine resources, and an overestimation of the ability of cod populations to recover (Grafton et al., 2009; Steele et al., 1992). The sharp decline in cod populations prompted the Canadian government to implement a cod moratorium in 1992, further impacting fishing-based livelihoods.

> "The high reliance on cod as a natural resource coupled with limited regional economic diversification affected incomes, livelihoods and employment opportunities in Newfoundland."

Similar to other cases reviewed, this case reveals income inequality effects both within the impacted sector and across the economy. Within the sector, some fishers were disproportionately affected due to their personal characteristics: tending to be older and with minimal

Figure 4. Demise of cod species: from nature loss to economic impact



transferable skills, many were left with fewer opportunities for retraining or for other employment (Berry, 2020), with the retraining programmes offered by the government in the offshore oil and gas industry in particular being unsuitable. In addition, the distribution of government support was argued to be uneven, creating inequalities and social divisions (Haedrich and Hamilton, 2000). The decline in cod and consequent introduction of the cod moratorium rendered about 30,000 people (12% of the regional labour force) unemployed in the fishing sector (Higgins, 2008; Rosano, 2022), but there were no records of unemployment effects on other industries. The reduction in employment opportunities consequently led to mass migration out of the affected regions, leading to lasting demographic shifts and a reduction in labour supply.

3.4. Soil loss in Malawi

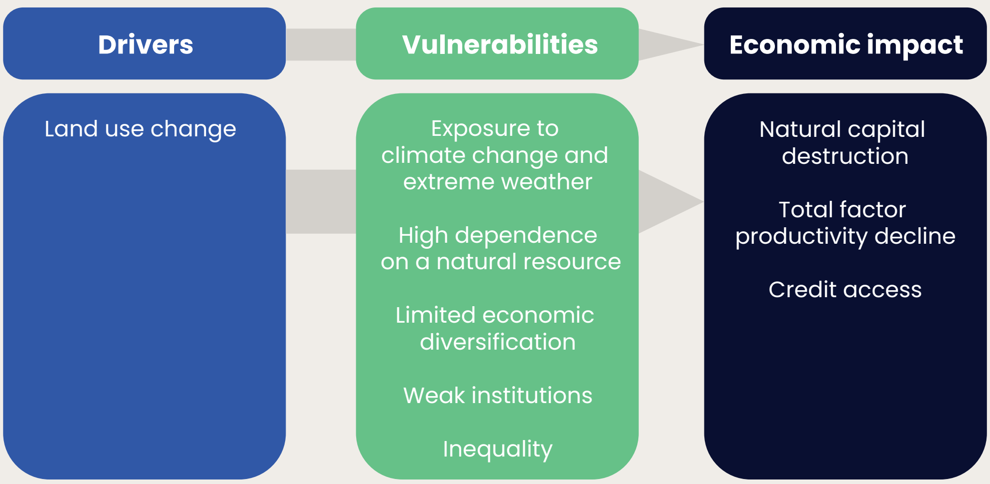
The case of *soil loss* in Malawi illustrates how land use change – mainly through deforestation and unsustainable land use practices (Li et al., 2021) – can drive excessive soil erosion, with lasting impacts on the economy. While land use change was the primary driver of nature loss here, causing significant soil erosion, the additional stress from climate change impacts and extreme weather have compounded these effects. Malawi and neighbouring countries are exposed to increased frequency and intensity of extreme weather events caused by climate change that exacerbate soil erosion. Soil erosion decreases agricultural productivity and increases susceptibility to natural disasters such as floods and landslides. Soil loss is a growing concern in Malawi and could reduce the country's agricultural production by up to 20% and GDP by up to 3% annually (Asfaw et al., 2020).

"While land use change was the primary driver, causing significant soil erosion, the additional stress from climate change impacts and extreme weather have compounded these effects."

In Malawi, vulnerabilities such as weak institutions and inequality have amplified the negative effects of soil erosion, particularly by creating incentives to adopt unsustainable agricultural practices (Shah et al., 2020). As soil erosion has reduced the availability of arable land, the local population have resorted to deforestation to expand agricultural land, which has further enhanced soil erosion, creating a vicious cycle.

The compounded negative effects of soil loss are transmitted to the economy through several channels. First, soil loss has led to lower crop yields, reducing Malawi's trading capabilities, exacerbated by the country's high dependence on arable land as a natural resource and high

Figure 5. Soil loss in Malawi: from nature loss to economic impact



reliance on environmental quality in the form of healthy soil for producing goods for exports. Malawi is a price taker in global markets, and the only way to increase its trade revenues is by increasing the quantity of goods produced, but this is now constrained by its reduced soil quality (FAO and ITPS, 2015; FAO et al., 2018).

Second, in extreme cases, soil erosion can completely deplete land's productivity, rendering land unsuitable for agriculture. This effectively manifests as a destruction of productive capital, as that land is no longer used in production, thus decreasing potential output.

Third, the impacts of soil erosion impose additional financial burdens on firms and households, compelling them to allocate resources towards damage repair and risk prevention rather than productive investments: for example, into sustainable agricultural practices or counteractive measures such as the use of fertilizers.

Lastly, soil loss impacts the economy via price effects, as lower productivity increases production costs and consequently increases the price of consumer goods. With the decline in soil quality, factor prices are affected as declining land productivity increases demand for land, pushing the land price upward (Asfaw et al., 2018). This causes changes in productivity of both capital and labour and relative wages in agricultural and non-agricultural sectors (ibid.).

These factors combined mean that households working in agriculture face a vicious cycle that perpetuates diminished productivity and constrained economic growth.

3.5. Aral Sea degradation

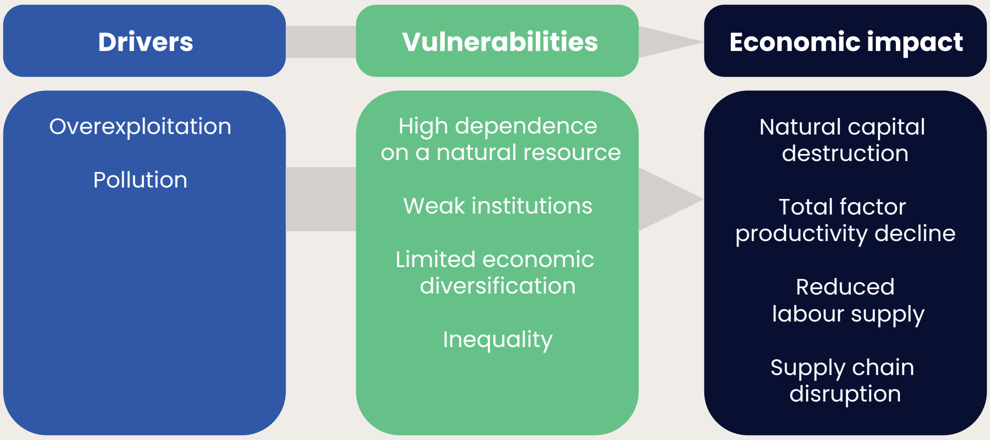
The case of the *Aral Sea degradation* highlights how a combination of nature loss drivers in the form of overexploitation and pollution can disrupt an ecosystem and result in resource depletion and habitat contamination. Overexploitation of water resources have depleted the Aral Sea, and pollution from agricultural run-off combined with the low water levels has devastated the Sea's ecosystem. As well as causing severe ecological changes, communities dependent on the Sea have faced major economic and social impacts.

This nature loss event began in the 1960s, when the Soviet Union started to divert the Amu Darya and Syr Darya rivers to irrigate vast areas of desert for cotton and other crops (White, 2014; Usmanova, 2003). The diversions drastically reduced the inflow of water to the Aral Sea, causing it to shrink rapidly, further exacerbated by the overextraction of groundwater.

Communities residing near the Aral Sea faced worsened economic outcomes as a result of several vulnerabilities. Weak institutions and poor environmental governance under the Soviet regime enabled the large-scale diversion of rivers, while institutional fragmentation and lack of cooperation among the Aral Sea basin countries (Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan and Tajikistan) led to mismanagement of water resources, as competing interests and priorities hindered the implementation of coordinated water management strategies. Several interventions to recover the Aral Sea were jointly implemented by countries of the basin and international donors (Micklin, 2007; Badescu and Schuiling, 2010), but came too late and were ultimately unsuccessful in preventing the almost total disappearance of the Sea. Limited economic diversification was a further source of vulnerability, as diversion

"As well as causing severe ecological changes, communities dependent on the Sea have faced major economic and social impacts."

Figure 6. Aral Sea degradation: from nature loss to economic impact



of the waters was motivated by production and export of cotton (White, 2014; Usmanova, 2003), which is grown as a monoculture and requires intensive irrigation.

The degradation of the Sea also directly caused the destruction of surrounding natural capital and changed the local climate, leading to more extreme winter and summer temperatures (Micklin, 2007). It significantly changed the landscape, through the demise of the Sea itself but also by destroying vegetation and arable land in surrounding areas (Bosch et al., 2007). The disaster devastated the fishery, tourism and agriculture sectors (Badescu and Schuiling, 2010), including the cattle breeding industry (Columbia University, n.d.), leading to cascading effects across different sectors, especially seafood manufacturing following the decline in fish species. These industries were affected both through diminished productivity directly due to pollution, and by disruptions in supply chains via provisioning of inputs.

"The Aral Sea disaster devastated the fishery, tourism and agriculture sectors, including the cattle breeding industry, leading to cascading effects across different sectors."

The Aral Sea disaster decreased potable water supply (through depletion of stocks and contamination) and increased air pollution (through dust and salt storms that carried toxic chemicals). This resulted in increased diseases such as respiratory illnesses and cancer (Anchita et al., 2021), and had adverse effects on labour productivity and supply (Zavialov, 2005; Micklin, 2007). The impacts were disproportionately high on infants, pushing infant mortality among the highest in the world as a result of toxins from agricultural runoff and pesticides contaminating blood and breastmilk.

4. Discussion

This review of historical nature loss events offers insights into how they transmit to the economy. These insights, which below we break down by theme, can help inform better risk management strategies for the financial sector and prompt a more integrated approach to addressing climate and nature risks.

4.1. Spillover effects and the supply chain

Nature loss impacts economies through various channels, including disrupting labour supply and diminishing total factor productivity. Destruction of (natural) capital impairs sectors reliant on ecosystem services, can cause supply chain disruptions as happened during the *COVID-19 outbreak*, places strain on global trade routes and inflates food prices.

Even smaller, localised shocks to a specific industry can cause spillover effects and cascade from one sector or from one location to another, thereby propagating throughout the whole economy (Almeida and Colesanti Senni, forthcoming). Depending on the size of the second-order effects, the overall resulting loss can spread beyond the initially affected sector. For instance, the repercussions of price increases in one sector triggered by nature loss events can extend to the national, regional or global economy, such as those experienced during *prolonged droughts* during the 2010s in the Middle East and the *COVID-19 outbreak*.

4.2. Nature-climate nexus

The historical examples demonstrate how climate and nature factors can cause significant economic impacts, such as in the cases of *olive tree disease, soil loss* and *mountain pine beetle invasion*. These types of interactions between weather anomalies and nature-related factors such as reduced soil quality or the spread of invasive species will only worsen as climate change and environmental degradation intensify. For example, in the case of the *mountain pine beetle invasion* that affected British Columbia, just a single year with a warm winter enabled this species to survive longer than usual, reproduce rapidly and transform from a natural regulator of pine trees into a biological threat.

Understanding how nature loss affects resilience against climate change can inform adaptation strategies and enhance long-term sustainability efforts. Climate-related incidents that are already causing risk and concern for policymakers in the finance sphere – such as disease outbreaks and increased health risks that result in reduced labour productivity, or landslides and soil erosion that result in asset destruction – are not isolated. These events are often preceded by nature degradation, including deforestation (Almeida et al., 2024) and ocean warming, highlighting the interconnectedness of ecosystem health and economic stability and the need for integrated climate-nature policy approaches.

> "Understanding how nature loss affects resilience against climate change can inform adaptation strategies and enhance long-term sustainability efforts."

4.3. Demographic changes

Migration

Nature loss events can create significant human capital and social security costs, affecting both individuals and governments. A critical dimension of this challenge is managing the consequences of nature loss-induced migrations. The *demise of cod species* in Canadian waters, *potato crop disease* in Ireland and the US *Dust Bowl* drove large-scale migrations, reshaped regional demographics and deepened socioeconomic inequalities.

There is an urgent need for research to better understand the drivers and dynamics of nature loss-induced migrations to aid policymaking. For example, research assessing the relative effectiveness of proactive measures, such as investing in infrastructure and social support systems in vulnerable regions, would be useful to understand the adverse impacts of population displacements and develop pathways for transition for affected communities.

Mortality and morbidity

Depending on the degree of nature loss, it can affect populations through impacts on mortality and morbidity. Mortality directly affects the size of the working age population and thus labour supply and total hours worked in the economy. Indirect effects of nature loss on labour are made via mortality of young people and infants, which can change future labour supply size and dynamics. The economic impacts are heterogeneous as they depend on existing demographic characteristics. Where the working age population is affected, increased morbidity can directly cause a decrease in total hours worked in the economy as well as a decrease in labour productivity. Lastly, where morbidity affects the young population that is yet to enter the labour market, it can affect long-term labour productivity and even human capital accumulation.

4.4. Heterogeneities in the impacts of nature loss

There is significant heterogeneity across nature loss events and their impacts, as demonstrated by our case studies. Importantly, impacts of nature loss might differ greatly by region or across different agents (Sumaila et al., 2015; O'Brien and Leichenko, 2003).

The burden from nature loss also depends on an agent's elasticity of substitution (Ferreira et al., 2023). For example, as seen in the case of the *harmful algal blooms* in the US and Canada, tourists can avoid their impacts by choosing an alternative destination but local tourism service providers might have close to zero substitutability. This can lead to either excessive unemployment at the regional level or migration from affected areas. Even if individuals migrate to find alternative sources of income, the economy of places and regions impacted by nature loss will continue to suffer. Similarly, companies that can more easily substitute their inputs will suffer less if their suppliers are affected by nature loss and, vice versa, companies that face a more elastic demand will suffer more.

The level of dependence of agents on nature also affects the size and the persistence of the impacts of a nature loss event. For instance, a nature loss event could adversely affect an economic agent's permanent income (e.g. by destroying physical or natural capital) or their transitory income (e.g. by damaging crops). In the case of the *harmful algal blooms*, this persistent nature loss event produced a transitory income shock to tourist agencies and a permanent income shock to hotel owners. The *demise of cod species* led to a permanent collapse of the fishing industry, which was the bedrock of the Newfoundland economy and led to lasting effects.

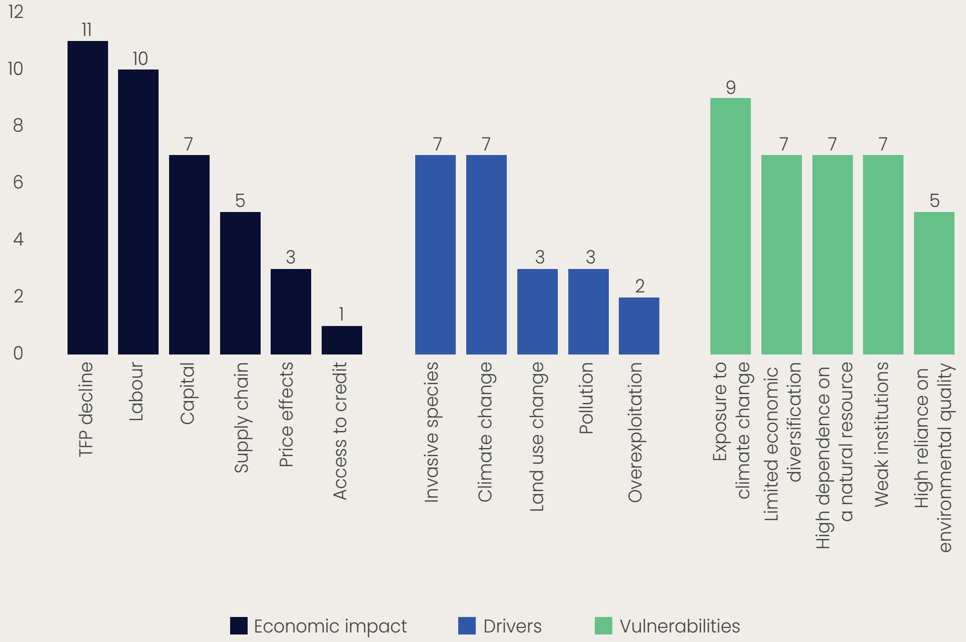
4.5. Repeated patterns

Repeated patterns emerge in the transmission channels linking drivers, vulnerabilities and economic impacts. By recognising these patterns and how drivers, vulnerabilities and economic impacts interact, we can better anticipate where and how future nature loss events might unfold. For instance, invasive species and climate change have consistently driven nature loss events, with existing vulnerabilities such as limited economic diversification or overreliance on environmental quality (as in the case of *olive tree disease*, for example) amplifying their negative economic consequences. Climate change not only triggers but also intensifies various nature loss events, worsening the effects of other drivers, particularly invasive species, land use change and pollution, strengthening the case for addressing climate and nature risk jointly.

A consistent finding across the cases reviewed is that nature loss almost invariably leads to a decline in total factor productivity (TFP). Further, nearly all 14 case studies of nature loss events have been associated with measurable impacts on labour supply and population dynamics. TFP has been recognised historically as a key driver of GDP growth (Hall and Jones,

"Nearly all 14 case studies of nature loss events have been associated with measurable impacts on labour supply and population dynamics."

Figure 7. Frequency of different economic impacts, drivers and vulnerabilities observed across the 14 case studies



1999); population growth is a significant driver of long-run growth, given that it fosters the development of human capital by increasing the pool of talent and skills available for economic and social advancement; and labour supply contributes at least twice as much as capital towards economic production. These impacts therefore emphasise the pervasive and far-reaching consequences of environmental degradation on the economy.

The review of historic nature loss events also provides some important lessons on building ecological and economic resilience against the impacts of nature loss. In particular, where original drivers might have been manageable under more resilient conditions, weak institutions and inequality enable them to intensify and cause extensive damage. The cases reviewed also shed light on the importance of diversifying the economy even at local and regional levels. While it is more difficult to overcome vulnerability to climate change and extreme weather events, awareness of these risks provides a basis for prioritising investments in climate adaptation and resilience and deepening the understanding of the climate-nature nexus.

“Where original drivers might have been manageable under more resilient conditions, weak institutions and inequality enable them to intensify and cause extensive damage.”

4.6. Implications for financial institutions and banking

Financial institutions can play a key role in dealing with the implications of nature loss. For instance, proactive risk management strategies and resilience-building measures can reduce the probability of a client defaulting and increasing their credit risk in the wake of nature-induced losses. For example, banks adopted effective risk mitigation strategies to support the economy during the *COVID-19 outbreak*. In the case of *soil loss* in Malawi, more support was needed for agricultural households affected by the income loss caused by declining yields. Additionally, solvency risks may arise from substantial property devaluation associated with nature loss events.

Regulating banking is essential in managing credit concentration, particularly towards specific sectors heavily impacted by nature loss. Concentrated credit exposures amplify the vulnerability of financial institutions to sector-specific risks, thereby exacerbating the potential fallout from nature-related events. Regulatory frameworks play a pivotal role in diversifying credit portfolios and ensuring that financial institutions maintain prudent levels of exposure across various sectors. By mitigating overreliance on sectors vulnerable to nature loss, banking regulation enhances the resilience of financial institutions and reduces systemic risks. This diversification strategy not only shields banks from the adverse effects of nature-induced shocks but also fosters financial stability by promoting a balanced and sustainable credit allocation approach.

"By mitigating overreliance on sectors vulnerable to nature loss, banking regulation enhances the resilience of financial institutions and reduces systemic risks."

5. Recommendations

Based on the review of these historical nature loss events, we identify several areas for policymakers' attention, focussing on the four recommendations that follow.

5.1. Adopting advanced modelling for nature loss impacts

Policymakers should consider the use of advanced modelling tools to better capture the heterogeneous economic impacts of nature loss. Current integrated nature-economy models often rely on representative agent frameworks, which fail to capture the varied costs borne by different economic agents, such as those differentiated by income levels. This oversight risks producing misleading estimates of aggregate effects.

Multi-agent macroeconomic models like TANK (Two-Agent New Keynesian) and HANK (Heterogeneous Agent New Keynesian) offer a more nuanced analysis of distributional and aggregate effects of nature loss, enabling more effective policy design. For instance, heterogeneous-agent models can evaluate the varied effects of macroeconomic support measures, including disaster relief and unemployment benefits, across different population groups. These models have been applied to areas including carbon pricing (Känzig, 2023) and net zero policies (Benmir and Roman, 2022). Expanding their use in the context of nature loss would support the development of equitable and efficient policies that address the complex economic implications of nature loss.

5.2. Implementing targeted financial and fiscal interventions to mitigate nature risks and enhance resilience

Policymakers and financial institutions must address the unique challenges of nature loss, including its interplay with climate risks and supply chain disruptions. Effective measures include fostering financial inclusion and implementing targeted support programmes to mitigate credit risks for vulnerable populations and promote economic recovery after nature-related shocks. Governments should employ fiscal tools such as tax incentives for sustainable practices and mandate asset and supply chain data disclosures to improve risk assessments. Strengthening fiscal preparedness for nature loss events and their inflationary impacts is essential. By enhancing governance and adopting proactive interventions, policymakers can mitigate the economic effects of nature loss, support resilience and safeguard vulnerable communities.

Moving from exposure analysis to a comprehensive nature-related risk assessment could enable the introduction of more targeted and effective financial sector action. Improving models and scenarios would enable more granular analysis of the potential financial risks of nature loss which would in turn enable a more targeted and context-specific regulatory and supervisory response. The financial sector could use those insights to adapt their risk management practices, ultimately shifting financing away from nature-harming investments.

5.3. Strengthening prudential regulation for nature-related risks

Strengthening prudential regulation is crucial to support banks in addressing financial risks linked to nature degradation (Alexander and Fisher, 2018). Nature loss exacerbates crises such as pandemics, mass migration of the working population and wars, impacting clients' creditworthiness and increasing the incidence of non-performing loans (NPLs) while threatening bank liquidity and solvency. Effective regulation should adopt a broader perspective, addressing indirect effects and spillovers. Solely restricting exposure to nature-reliant sectors risks worsening nature-related and macroeconomic vulnerabilities. Flexible measures, similar to the debt moratoria offered during COVID-19, can mitigate impacts while supporting vulnerable households and businesses exposed to nature-related risks. Proactive, balanced regulation allows banks to manage risks without perpetuating financial distress or poverty.

"Proactive, balanced regulation allows banks to manage risks without perpetuating financial distress or poverty."

5.4. Ensuring timely intervention to address nature degradation

Crossing ecological thresholds through habitat degradation or resource overexploitation can cause permanent ecosystem collapse (Möllman et al., 2021), as demonstrated by the Aral Sea degradation and the demise of cod species in Canadian waters, with climate change further intensifying such risks. Timely intervention to avoid surpassing ecological tipping points is critical to preventing irreversible nature loss.

References

Adams CM and Larkin SL (2013) *Economics of harmful algal blooms: literature review. Food and Resource Economics Department Project Report*. University of Florida.

Alexander K and Fisher P (2018) *Banking regulation and sustainability*. SSRN 3299351.

Almeida E and Colesanti Senni C (forthcoming) *Analyzing the impact of nature shocks on supply chains: Methodological approaches and insights*.

Almeida E, Lagoa D and Vasudhevan T (2024) *Hidden harms: the economic and financial consequences of deforestation and its underlying drivers*. London: CETEx and Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

Anchita A Z, Khaibullina Z, Kabiyev Y Persson KM and Tussupova K (2021) Health impact of drying Aral Sea: One health and socio-economical approach. *Water* 13(22): 3196.

Asfaw S, Orecchia C, Pallante G and Palma A (2018) *Soil and nutrients loss in Malawi: an economic assessment*. Food and Agriculture Organization of the United Nations and the UNDP-UNEP Poverty-Environment Initiative and the Ministry of Agriculture, Irrigation and Water Development, Malawi.

Asfaw S, Pallante G and Palma A (2020) Distributional impacts of soil erosion on agricultural productivity and welfare in Malawi. *Ecological Economics* 177: 106764.

Badescu V and Schuiling RD (2010) Aral Sea; irretrievable loss or Irtysh imports? *Water Resources Management* 24: 597-616.

Benmir G and Roman J (2022) *The distributional costs of net-zero: A HANK perspective*. Working paper. https://ghassanebenmir.com/files/job-market-paper.pdf.

Berry D (2020) *Cod Moratorium of 1992*. The Canadian Encyclopedia. https://www.thecanadianencyclopedia.ca/en/article/cod-moratorium-of-1992.

Bilbiie FO, Känzig DR and Surico P (2022) Capital and income inequality: An aggregate-demand complementarity. *Journal of Monetary Economics* 126: 154-169.

Boldrini S, Ceglar A, Lelli C, Parisi L and Heemskerk I (2023) *Living in a world of disappearing nature: physical risk and the implications for financial stability*. ECB Occasional Paper (2023/333).

Bosch K, Erdinger L, Ingel F, Khussainova S, Utegenova E, Bresgen N et al. (2007) Evaluation of the toxicological properties of ground- and surface-water samples from the Aral Sea Basin. *Science of the Total Environment* 374(1): 43-50.

Bosso L, Di Febbraro M, Cristinzio G, Zoina A and Russo D (2016) Shedding light on the effects of climate change on the potential distribution of Xylella fastidiosa in the Mediterranean basin. *Biological Invasions* 18: 1759-1768.

Ceglar A, Parker M, Pasqua C, Boldrini S, Gabet M, and van der Zwaag S (2024) Economic and financial impacts of nature degradation and biodiversity loss. *Economic Bulletin Articles* 6.

Cevik S and Jalles JT (2023) For whom the bell tolls: Climate change and income inequality. *Energy Policy* 174: 113475.

Columbia University (n.d.) *The Aral Sea Crisis*. Columbia University. Web page. https://www.columbia.edu/~tmt2120/introduction.htm.

Court C, Ferreira J, Ropicki A, Qiao X and Saha B (2021) *Quantifying the socio-economic impacts of harmful algal blooms*. University of Florida Food and Resource Economics Department.

Dasgupta P (2021) *The economics of biodiversity: the Dasgupta review*. HM Treasury.

Dodds WK, Bouska WW, Eitzmann JL, Pilger TJ, Pitts KL, Riley AJ et al. (2009) Eutrophication of US freshwaters: analysis of potential economic damages. *Environmental Science and Technology* 43(1):12-9.

Elderson F (2024) *Taking account of nature, naturally*. Speech at the tenth Green Finance Forum "Innovate in Nature". Frankfurt am Main, 19 November. https://www.ecb.europa.eu/press/key/date/2024/html/ecb.sp241119~3eeb812c74.en.html.

Espinosa R, Tago D and Treich N (2020) Infectious diseases and meat production. *Environmental and Resource Economics* 76(4): 1019-1044.

Everard M, Johnston P, Santillo D and Staddon C (2020) The role of ecosystems in mitigation and management of Covid-19 and other zoonoses. *Environmental Science and Policy* 111: 7-17.

Ferreira JP, Saha B, Carrero GC, Kim J and Court C. (2023) Impacts of red tide in peer-to-peer accommodations: A multi-regional input-output model. *Tourism Economics* 29(3): 812-834.

Food and Agriculture Organisation of the United Nations [FAO], United Nations Environment Programme [UNEP] and United Nations Development Programme [UNDP] (2018) *Impact of Soil Loss in Malawi: Microeconomic effects of soil and nutrient loss.*

Food and Agriculture Organisation of the United Nations [FAO] and The Intergovernmental Technical Panel on Soils [ITPS] (2015) *Status of the World's Soil Resources (SWSR) – Main Report*. Rome, Italy: Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils.

Fraga H, Pinto JG and Santos JA (2019) Climate change projections for chilling and heat forcing conditions in European vineyards and olive orchards: A multi-model assessment. *Climatic Change* 152: 179-193.

Grafton RQ, Kompas T and Van Ha P (2009) Cod today and none tomorrow: the economic value of a marine reserve. *Land Economics* 85(3): 454-469.

Hall NS, Litaker RW, Fensin E, Adolf JE, Bowers HA, Place AR et al. (2008) Environmental factors contributing to the development and demise of a toxic dinoflagellate (Karlodinium veneficum) bloom in a shallow, eutrophic, lagoonal estuary. *Estuaries and Coasts* 31: 402-418.

Haedrich RL and Hamilton LC (2000) The fall and future of Newfoundland's cod fishery. *Society & Natural Resources*, 13(4): 359-372.

Hall RE and Jones CI (1999) Why do some countries produce so much more output per worker than others? *The Quarterly Journal of Economics* 114(1): 83-116.

Higgins J (2008) *Economic impacts of the cod moratorium*. Newfoundland and Labrador Heritage. Web page. https://www.heritage.nf.ca/articles/economy/moratorium-impacts.php.

Hoagland PA, Anderson DM, Kaoru Y and White AW (2002) The economic effects of harmful algal blooms in the United States: estimates, assessment issues, and information needs. *Estuaries* 25: 819-837.

Hopkins DL and Purcell AH (2002) Xylella fastidiosa: cause of Pierce's disease of grapevine and other emergent diseases. *Plant Disease* 86(10): 1056-1066.

Inklaar R, de Jong H, Bolt J and van Zanden JL (2018) Rebasing 'Maddison': new income comparisons and the shape of long-run economic development. *GGDC Research Memorandum*; Vol. GD- 174. Groningen Growth and Development Center.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] (n.d., a) *Models of drivers of biodiversity and ecosystem change*. Web page. https://www.ipbes.net/models-drivers-biodiversity-ecosystem-change.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] (n.d., b) *Glossary*. Web page. https://www.ipbes.net/glossary.

Jin D, Thunberg E and Hoagland P (2008) Economic impact of the 2005 red tide event on commercial shellfish fisheries in New England. *Ocean and Coastal Management* 51(5): 420-429.

Johnson JA, Ruta G, Baldos U, Cervigni R, Chonabayashi S, Corong E et al. (2021) *The economic case for nature: A global earth-economy model to assess development policy pathways*. World Bank. http://hdl.handle.net/10986/35882.

Känzig DR (2023) *The unequal economic consequences of carbon pricing*. National Bureau of Economic Research (No. w31221).

Kashian R, Eiswerth ME and Skidmore M (2006) Lake rehabilitation and the value of shoreline real estate: Evidence from Delavan, Wisconsin. *Review of Regional Studies* 36(2): 221-238.

Li C, Kandel M, Anghileri D, Oloo F, Kambombe O, Chibarabada TP et al. (2021) Recent changes in cropland area and productivity indicate unsustainable cropland expansion in Malawi. *Environmental Research Letters* 16(8): 084052.

Mainka SA and Howard GW (2010) Climate change and invasive species: double jeopardy. *Integrative Zoology* 5(2): 102-111.

Michalak AM, Anderson EJ, Beletsky D, Boland S, Bosch NS, Bridgeman TB et al. (2013) Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. *Proceedings of the National Academy of Sciences* 110(16): 6448-6452.

Micklin P (2007) The Aral sea disaster. *Annual Review of Earth Planet Science* 35(1): 47-72.

Möllmann C, Cormon X, Funk S, Otto SA, Schmidt JO, Schwermer H et al. 2021. Tipping point realized in cod fishery. *Scientific Reports*, 11(1): 14259.

Network for Greening the Financial System [NGFS] (2023) *Recommendations toward the development of scenarios for assessing nature-related economic and financial risks*. NGFS

Network for Greening the Financial System [NGFS] and International Network for Sustainable Financial Policy Insights, Research And Exchange [INSPIRE] (2022) *Central banking and supervision in the biosphere: An agenda for action on biodiversity loss, financial risk and system stability*. Final Report of the NGFS-INSPIRE Study Group on Biodiversity and Financial Stability. NGFS-INSPIRE occasional paper.

O'Brien KL and Leichenko RM (2003) Winners and losers in the context of global change. *Annals of the Association of American Geographers* 93(1): 89-103.

Parsons GR, Morgan A, Whitehead JC and Haab TC (2006) The welfare effects of pfiesteria-related fish kills: A contingent behavior analysis of seafood consumers. *Agricultural and Resource Economics Review* 35(2): 348-356.

Prasad M, Wahlqvist P, Shikiar R and Tina Shih YC (2004) A review of self-report instruments measuring health-related work productivity: a patient-reported outcomes perspective. *Pharmacoeconomics* 22: 225-244.

Ranger N, Alvarez J, Freeman A, Harwood T, Obersteiner M, Paulus E et al. (2023) *Green Scorpion: the Macro-Criticality of Nature for Finance–Foundations for scenario-based analysis of complex and cascading physical nature-related risks*. Oxford: Environmental Change Institute, University of Oxford.

Root TL, Price JT, Hall KR Schneider SH, Rosenzweig C and Pounds JA (2003) Fingerprints of global warming on wild animals and plants. *Nature* 421(6918): 57-60.

Rosano M (2022) Cod moratorium: How Newfoundland's cod industry disappeared overnight. *Canadian Geographic*, 11 July.

Sanseverino I, Conduto D, Pozzoli L, Dobricic S and Lettieri T (2016) *Algal bloom and its economic impact*. European Commission, Joint Research Centre Institute for Environment and Sustainability.

Schrank WE (2005) The Newfoundland fishery: ten years after the moratorium. *Marine Policy* 29(5): 407-420.

Shah R, Ferguson R and Khonje M (2020) *The Past, Present, and Future of Land Use in Malawi: A Background Review*. Malawi Agricultural Policy Advancement and Transformation Agenda Institute [MwAPATA Institute].

Steele DH, Andersen R and Green JM (1992) The managed commercial annihilation of northern cod. *Newfoundland Studies* 8(1): 34-68.

Sumaila UR, Lam VW, Miller DD Teh L, Watson RA, Zeller D et al. (2015) Winners and losers in a world where the high seas is closed to fishing. *Scientific Reports* 5(1): 8481.

University of Cambridge Institute for Sustainability Leadership [CISL] and HSBC (2022) *Nature-related financial risk: use case. Impact of water curtailment on credit rating of heavy industry companies in East Asia*.

Usmanova RM (2003) Aral Sea and sustainable development. *Water Science and Technology* 47(7-8): 41-47.

Walther GR, Post E, Convey P Menzel A, Parmesan C, Beebee TJ et al. (2002) Ecological responses to recent climate change. *Nature* 416(6879): 389-395.

White KD (2014) Nature and economy in the Aral Sea basin. In Micklin P, Aladin NV and Plotnikov I (Eds) *The Aral Sea: The Devastation and Partial Rehabilitation of a Great Lake*: 301-335. Springer.

World Bank and Bank Negara Malaysia [BNM] (2022) *An Exploration of Nature-Related Financial Risks in Malaysia.*

Yang Y (2023) Redistributive inflation and optimal monetary policy. *SSRN Working Paper* (4275770).

Zavialov PO (2005) *Physical oceanography of the dying Aral Sea*. Springer Science & Business Media.

Appendix. Description of drivers, vulnerabilities and economic impacts

Drivers of nature loss are factors or processes that directly or indirectly cause the degradation or destruction of nature that we refer to in this paper as a 'nature loss event'.

- **Invasive species and pathogens:** those that are introduced or emerge outside their natural ecosystem, whose introduction or spread pose threats to biological diversity (IPBES, n.d., b). In this paper, pathogens (bacteria, viruses, fungi and parasites) are considered a subset of invasive species, causing diseases in animals, plants or humans, and can spread through both natural means and human activities (e.g. global travel or trade), as exemplified by COVID-19.
- **Land use change:** the conversion of land or management of ecosystems, e.g. through deforestation, urbanisation, the intensification of agricultural management or forest harvesting (ibid.).
- **Overexploitation:** the harvesting of species from the wild at rates faster than by which natural populations can recover (ibid.), including through overfishing and overgrazing.
- **Pollution:** occurs when contaminants are introduced into the natural environment and results in adverse ecological changes, often leading to negative consequences for human health.
- **Climate change:** a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates, and can be caused both by natural processes and human activities. It can cause disruption e.g. through excessive rainfall and prolonged droughts. Climate change can also trigger or amplify other drivers of nature loss. For example, it can create conditions for invasive species to thrive or worsen the effects of pollution.

Vulnerabilities are factors or circumstances that worsen the initial nature loss event by affecting its geographical distribution, duration and intensity or its transmission to the macroeconomy. Vulnerabilities can stem from environmental, economic or governance characteristics of a region or country.

- **Exposure to climate change and extreme weather** amplifies the impacts of a nature loss event. When acting as a vulnerability, climate change does not trigger the loss *per se*, as it would happen absent of climate change too, but it affects pervasiveness or the duration of a loss. Climate change can worsen the spread of invasive species (Root et al., 2003; Walther et al., 2002) or exacerbate loss of ecosystem services such as water availability, temperature regulations and soil quality.
- **Limited economic diversification** amplifies nature loss when a country or region's economy is overly dependent on a particular natural resource or environmental quality. The loss of this natural resource, or the ecosystem services it provided, can lead to severe negative implications that reverberate through the economy, including through supply chains.
- **High dependence on a natural resource** refers to a situation where individuals, regions or countries depend on a certain aspect of nature as a main source of their employment and income or their consumption.
- **High reliance on environmental quality** exacerbates the negative economic implications of nature loss. Sectors that depend on environmental quality include tourism, real estate, agriculture and renewable energy. For example, the success of tourism depends on healthy, safe and picturesque environments and the agriculture sector is dependent on pollinators. The loss of these ecosystem services can lead to declines in economic revenue or require costly substitutions.
- **Weak institutions** refer to governance structures and systems that lack the capacity, authority or effectiveness to enforce laws, deliver services and maintain order.
- **Inequality** in the context of nature loss refers to the different exposure and ability to cope with the costs generated by ecosystem degradation. Nature loss and environmental degradation are intricately linked with inequality (Cevik and Jalles, 2023). In particular, income inequality is bidirectionally linked to the nature loss: it affects exposure to nature loss risk as it leads to disproportionate resource consumption and environmental degradation, while the nature loss itself contributes to deepening income inequalities as nature drives asymmetric effects on different individuals.

Economic impacts refer to the effects of nature loss events that manifest within the economy and with sufficient data and adequate methodologies could be documented and quantified.

- **Potential output** is the highest feasible output that an economy can achieve when operating at full capacity (i.e. using all available factors of production).
- **Labour supply** refers to the total hours that workers are willing and able to spend working at given wages under existing market conditions.
- **Capital** is a long-term factor of production that gradually transfers its value to the final product through the production process (in contrast to materials that are short-term and principally transferring their total value to the finished product in a single production process). **Natural capital** includes environmental assets such as forests, water surfaces and land. Other forms of capital are physical capital, such as infrastructure, machinery and buildings, and intangible capital such as human capital and institutions.
- **Total Factor Productivity (TFP)** is a measure of the efficacy at which an economy combines factors of production in a production process. From the perspective of potential output, TFP represents the portion of it that is not explained by the number of main factors of production, which is why it is commonly viewed as a residual.
- **Supply chain disruptions** stem from infrastructure damage or logistical challenges, including disruptions in supply (quantity or quality) of intermediary goods.
- **Price effects** are price pressures that result from nature loss and can change the factor, input or final prices of goods and services. They also cover changes in wealth driven by nature loss (e.g. changes in property values) and additional expenses to cope with the consequences of nature loss.
- **Access to credit** refers to the ability of an individual or a firm to obtain funds through borrowing, enabling them to finance various needs (including counteracting the negative effects from nature loss) and investments (including protection from nature loss).

About the authors

Elena Almeida is a Senior Policy Fellow at CETEx.

Chiara Colesanti Senni is a Research Fellow at the University of Zurich and a Visiting Fellow at CETEx.

Jelica Rastoka is a Research Assistant to CETEx.

Acknowledgements

The authors would like to thank Oliver Braunschweig, Antoine Champetier, Joseph Fayertag, Ben Filewod, Lea Reitmeier, Daniel Sumner, Lea Naemi Weigand and Jessica Xu for their review comments on a draft version of this paper. The paper was edited by Georgina Kyriacou with layout by Zoe Kay.

Disclaimer

The authors declare no conflict of interest in the preparation of this paper. The views in this paper are those of the authors and do not necessarily represent those of the host institutions or their funders.

CETEx – the Centre for Economic Transition Expertise – was established in 2024 at the London School of Economics and Political Science as a specialised research and policy centre to support the ambitious reforms required to deliver sustainable, inclusive and resilient economies and financial systems across Europe. The Centre is hosted by the Grantham Research Institute on Climate Change and the Environment and has founding funding from the Sequoia Climate Foundation, ClimateWorks Foundation, Children's Investment Fund Foundation, Sunrise Project and European Climate Foundation.

www.cetex.org