A supervisory framework for assessing nature-related financial risks

Annexes

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Definitions

The following listed terms have the sole purpose of giving the reader an understanding of the concepts that are discussed throughout this report and do not reflect the official view of the OECD.

Biodiversity (or biological diversity): According to the UN Convention on Biological Diversity (CBD), biodiversity is "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (CBD, 1992[1]).

Nature-related risks[1]: refers to economic risks which stem from nature-related losses and have an impact on economic activities and their associated corporates, as well as the cost of goods and services.

Nature-related financial risks: nature-related financial risks are the sources of potential losses for market participants associated with the deterioration of nature. Such losses include the alteration of portfolios' revenues or balance sheets or the adverse impacts of financial decisions. Additionally, the accumulation and potential compounding effect of these risks may lead to more systemic financial risks. Building on Mark Carney's initial classification of financial risks posed by climate change, this input has been adapted to address nature. For this reason, nature-related financial risks tend to be classified into two types of risks:

- **Physical risks**: Sources of potential losses in production, service delivery and the financial position of a firm caused by direct shocks associated to nature loss. These risks can either be chronic (e.g. droughts causing damages in agriculture), acute (e.g. diseases spreading due to alien species), or both (e.g. disruption of the hydrological cycle caused by deforestation) (NGFS - INSPIRE, 2022[2]).
- **Transition risks**: may stem from misalignment between companies' business model and strategy, and actions related to the restoration of nature. Specifically driven by changes in climate and environmental policy, technology advancements, and changes in consumer and investor sentiment. These may lead to economic and financial risk to both corporate and financial institutions. Transition risks may additionally occur from policies implemented in response to the materialisation of physical risks, which may not directly or indirectly serve to preserve nature.

There exist, nonetheless, additional subset of risks related to nature-related financial risks. For example:

[1] Nature-related risks may turn into nature-related financial risks if their economic impact is financially material and may potentially lead to substantial risks for financial institutions.

- **Liability risks**: The possibility of a market participant being held responsible for an action or inaction, resulting in a financial loss. Liability risks associated with nature loss can materialise from the failure to prevent nature loss or for the consequences of an action that leads to ecosystem damage (Barker, Mulholland and Onifade, 2020[3]).

Direct drivers of biodiversity loss: Direct drivers of (and pressures on) biodiversity loss include all external factors that lead to the deterioration of biodiversity, which tend to be the result of human interventions/activities. The five main direct drivers of biodiversity loss are: land and sea-use change; direct exploitation of organisms; climate change; pollution; and invasive alien species (IPBES, 2019[4]).

Ecosystems: Ecosystems refers to the dynamic complex of all living organisms (plant, animal, fungi and microorganism communities), and their non-living environment interacting as a functional unit (IPBES, 2019[4]).

Ecosystem services: Ecosystem services are defined as the benefits people obtain from ecosystems, and have been categorised as provisioning, regulating, cultural and supporting services (Millenium Ecosystem Assessment, 2005[5]).

Nature: The term nature is used in different ways, depending on the context within which it is applied. Both the Taskforce for Nature-related Financial Disclosures (TNFD) and the Network for Greening the Financial System (NGFS) closely follow the definition provided by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES): “The nonhuman world, including coproduced features, with particular emphasis on living organisms, their diversity, their interactions among themselves and with their abiotic environment” (IPBES, 2019[4]). The Dasgupta Review uses the term ‘nature’ to refer to the natural world and uses it synonymously with other terms, including for example, natural capital, the natural environment, and the biosphere.

In this report, the term ‘nature’ refers to all physical aspects of the natural world (both biotic and abiotic), including species, the landscape and other features and products of the earth, including geology, atmosphere, soil, and water. References to ‘broader nature’ refer only to the abiotic components of nature. Biodiversity is an integral component of nature.

Annex 1: Technical assessment tools

Annex 1 provides a non-exhaustive list of assessment approaches and tools which financial authorities may use to undertake a technical assessment of the economic and financial risks. It focuses on tools which enable the technical assessment of economic risks, both at a micro- and macroeconomic level. However, due to the complexity and emerging nature of assessing nature related risks, the approaches listed can have varying levels of limitations.

Measurement approaches

Understanding the economic consequences of potential biodiversity-related shocks and their impacts and dependencies on economics requires an understanding of how ecosystems function (Svartzman et al., 2021[6]). A major difficulty in this is the non-linearity and complexity of ecosystems. In this regard, the measurement of biodiversity impacts and dependencies requires multiple indicators to capture progress across various spatial and ecological dimensions. Table 1 below shows the methodologies, tools and databases currently available.

Table 1. Measurement Approaches: databases and methodologies

Measurement Approach	Description
ENCORE database and methodology	ENCORE is a database that maps sector-based impacts and dependencies on ecosystem services for sectors of the economy.
BIA-GBS database and methodology	BIA-GBS measures impacts (i.e., the biodiversity footprint) and dependencies of companies and sovereign entities. The impact is assessed in Mean Species Abundance (MSA.km2) the biodiversity dimension of ecosystem integrity, by linking data on economic activities to pressures on biodiversity and translating them into biodiversity impacts.
GLOBIO model	The GLOBIO Model estimates biodiversity footprint (i.e. impacts), measured in Mean Species Abundance (MSA) as a function of six human pressures: land use, road disturbance, fragmentation, hunting, atmospheric nitrogen deposition and climate change. The core of the model consists of quantitative pressure-impact relationships that have been established based on extensive terrestrial biodiversity databases.
Corporate Biodiversity Footprint	The Corporate Biodiversity Footprint (CBF) assess the annual impacts on ecosystem services and biodiversity of the underlying activities of a corporate or a financial institution. The CBF assesses the impacts of business activities on nature and ecosystem services through four main categories of environmental pressures: Change of land use, Climate change with GHG emissions, Air Pollution and Water Pollution.
IBAT	The Integrated Biodiversity Assessment Tool (IBAT) offers the possibility to give access to three global biodiversity datasets: IUCN Red List of Threatened Species, World Database on Protected Areas and the World Database of Key Biodiversity Areas. IBAT exploits the most up to date information from each of these datasets to ensure accuracy for biodiversity data. The database is used to assess both impact and dependencies.
The Nature-Finance Alignment Tool	The Nature-Finance Alignment Tool assesses quantitatively the alignment of public and private financial flows with nature positive outcomes. The tool provides a score from 0-10 on the alignment of financial data, where 0 means no alignment and 10 stands for complete alignment. The scoring methodology is based on a country framework and a sector framework.
EORA MRIO	The Eora global supply chain database is a multi-region input-output table (MRIO) model that provides a time series of Input-Output tables, matching environmental, social and economic indicators for 15 909 sectors across 190 countries. The IO tables provided cover the following

Measurement Approach	Description
	categories: greenhouse gas emissions, labour inputs, air pollution, energy use, water requirements, land use, primary agricultural inputs (including 172 types of crops) and the Human Appropriation of Net Primary Productivity.
EXIOBASE	EXIOBASE input-output table has the main goal to harmonize and provide supply-use economic linked variable for a large number of countries, estimating quantitative environmental metrics (e.g. emissions and resource extractions) by industry and sector. Given that, EXIOBASE Input-Output tables can be used to measure the impacts on ecosystem services and biodiversity (and more broadly, the environmental impacts) associated with the final production or consumption of goods.
Ecoinvent	The ecoinvent Database is a Life Cycle Inventory (LCI) database that supports various types of sustainability assessments. It is a database that covers a set of sectors at global and regional level. It gives quantitative and qualitative information about more than 18 000 activities.
Value Chain Footprinting Dashboard	The Value Chain Footprinting dashboard provides estimates of the environmental and ecosystem service impacts of production and consumption activities. It incorporates the production of over 160 agricultural products and selected environmental impacts and risks associated with these products in 240 producing countries and territories within national and international supply chains.

Source: Assessing Biodiversity-Related Financial Risks: Navigating the landscape of existing approaches (OECD, 2023[7]).

Macroeconomic Assessment Approaches

In order to accurately quantify the economic implications of ecosystem loss, it is crucial to consider the significant heterogeneity and feedback effects involved. Although the complexity of this issue and its relatively nascent stage of development pose challenges, several financial institutions have undertaken diverse methodologies to assess impacts and dependencies on biodiversity and ecosystem services. Table 2 and Table 3 below show the main macro and microeconomic models currently available for financial authorities.

Table 2. Macroeconomic Assessment Approaches: models and methodologies

Macroeconomic approach	Description
Integrated Assessment Models (IAMs)	Integrated Assessment Models (IAMs) provide policy-relevant insights by offering quantitative descriptions of the interactions between physical earth systems and human or economic system. The modelling approach is integrated, including information from both the biophysical and the economic systems. It is a partial-equilibrium model which represents the primary land-use sectors, including agriculture and forestry, and was developed by the International Institute for Applied Systems Analysis (IIASA).
GTAP-InVEST Earth-Economy Model	A recent Earth-Economy Model combines the Global Trade Analysis Project (GTAP) computable general equilibrium (CGE) model, a set of ecosystem service models, and a spatial simulator, to create an integrated ecosystem-economy model. The general equilibrium model is linked to a suite of high-resolution, spatially explicit ecosystem services models, most notably through endogenously determined land-use change which create input maps used in the ecosystem service models.
Integrated Nature and Climate Scenarios	The Inevitable Policy Response (IPR) has published integrated climate and nature scenarios for investors. IPR have integrated nature transition considerations into their Forecast Policy Scenario (FPS), to create FPS + Nature. The scenario focuses on forceful response to climate change and nature loss out to 2030 and 2050. The FPS+N scenario focuses on nature-related policies which impact land-use, with the impacts filtering through the real economy and interacting with climate policies, specifically across food, energy, nature-related good, services, and assets, supply chains, and the global environment.

Source: Assessing Biodiversity-Related Financial Risks: Navigating the landscape of existing approaches (OECD, 2023[7]).

Microeconomic Assessment Approaches

Table 3. Microeconomic Assessment Approaches: models and methodologies

Microeconomic Approach	Description
System of Environmental Economic Accounting–Ecosystem Accounting SEEA EA	SEEA EA is a framework of ecosystem accounting to organise biophysical data on ecosystems and ecosystem services, accounting for spatially explicit information. The framework tracks changes in the extent and condition of ecosystems, 'valuing ecosystem services and assets and linking this information to measures of economic and human activity. The approach of ecosystem accounting provides a method to assess the impacts and dependency of economic as well as human activity on the environment.
Handbook for Nature-related Financial Risks	The Cambridge Institute for Sustainable Leadership (CISL) have developed a framework to identify nature-related risks. Its purpose is to: (i) define key concepts; (ii) detail transmission channels that make nature loss a financial risk; and (iii) outline a framework that banks and asset managers can use to identify nature-related financial risks. The framework identifies the relevant risk driver types (physical, transition, and liability risk) as well as the transmission channels (through risk manifestation and resultant impact on companies) to financial risks (credit, market, liquidity, and business risk). This is conducted in a four-step approach – identify the type of risk, how the risk manifests, the impact on companies, and the resultant financial risk.
TNFD LEAP FI Approach	The Taskforce on Nature-related Financial Disclosures has developed a framework for market participants to disclose nature-related risks and opportunities. The LEAP approach outlines four main ways for companies to undertake when assessing nature-related risks and opportunities. 1. Locate, the interface with nature; 2. Evaluate, dependencies & impacts; 3. Assess, material risks & opportunities; 4. Prepare, to respond & report. Within each of these four steps, the TNFD offers additional guidance on actions companies could undertake to achieve each one of the steps

Source: Assessing Biodiversity-Related Financial Risks: Navigating the landscape of existing approaches (OECD, 2023[7]).

Annex 2: Data gaps assessment

Annex 2 provides an overview and assessment of the current gaps related to data and assessment tools to allow for the technical assessment of economic and financial risks related to nature. Furthermore, the assessment includes recommendations to bridge these gaps.

Gaps assessment

The implementation of the methodological framework requires an understanding of where gaps exist with regards to data and assessment tools and what can be done to tackle these gaps.

The first gap can be identified in the **access to data on transmission channels:** Several approaches to assess financial risks and dependencies on biodiversity (including the approaches developed in the Handbook for Nature-related Financial Risks and the corporate and financial disclosure approaches developed by TNFD) require identification of the financial and economic transmission channels by which geographically located changes in biodiversity influence financial outcomes (CISL, 2021[8]). This requires geo-location data of economic assets at risk, and the relationship between those assets and their investors or economic actors downstream in the value-chain. Several initiatives exist which are increasing the availability of these areas of data. However, further action is needed to increase transparency and data availability in these areas.

The second gap regards **multidimensional indices:** Recent literature suggests a broader consensus on the complexity of biodiversity and its measurements. A single metric or index is generally insufficient to provide a comprehensive view of the state of biodiversity, making it necessary to use them together. A number of studies suggest that different metrics may be used together to provide a broader understanding of biodiversity processes (Scholes and Biggs, 2005[9]). For example, while the Potentially Disappeared Fraction (PDF) reflects the percentage of species richness that could be lost due to environmental pressures, the Biodiversity Impact Metric (BIM) could help understand the key element in a supply chain causing biodiversity losses. When used together, these metrics could deliver more granular information. Additional research is necessary to determine the viability of multidimensional indices as instruments to measure biodiversity risk.

The third gap in the assessment can be identified in the need for **standardisation and comparability of data and outcomes:** Each biodiversity measurement has its own assumptions and characteristics. Considering the need to use different metrics simultaneously to obtain comprehensive information on different aspects on the state of biodiversity, there could be issues with reconciliation of data due to the differences in methodologies. Quality checks and verification for nature-related data have been recently called for by many financial institutions to ensure comparability of data and analyses. Thus, further developments are required to explore approaches of standardisation to ensure coherent and comparable data.

Lastly, gaps exist regarding the **translation of biodiversity data into useful financial metrics:** Analysed metrics and indicators focus on the delivery of information related to environmental considerations. This means that they provide enough information for driving environmental decision making. Nevertheless, this information remains insufficient for finance-related purposes. For this reason, further actions are needed to effectively translate current biodiversity metrics into relevant information that can provide insights on biodiversity risk. This also accounts for biodiversity's role in mediating climate risks. Further research needs to identify decision-useful biodiversity data that can be translated into financial risks.

Annex 3: Case studies

Annex 3 provides further information on the illustrative case studies to demonstrate the differing economic risks stemming from direct and indirect impacts. These case studies are grounded in evidence from historical events and academic studies but have forward-looking dimensions to explain their relevance with regards to nature loss.

Liability Risk

Understanding the link between the different types of economic risk arising from biodiversity-related losses is crucial. It is also important to understand what the liability risks are, whether they stem from physical or transitional risks. Liability risk is defined as the risk that arises when parties who have suffered biodiversity-related loss or damage seek compensation from those they hold responsible (OECD, 2019[10]). The risk of legal suits founded in biodiversity may increase as disclosure and external reporting on companies' biodiversity impact assessments increases. (OECD, 2019[10]). It represents an important component of the wider risk methodological framework, and it may arise both from the physical risk associated with environmental changes and the transition risk inherent in the shift towards a low-carbon economy.

For example, in high-risk regions prone to severe environmental degradation, corporates and financial institutions may be increasingly vigilant of their value chain activities, whether these activities detrimentally impact biodiversity or perpetuate other environmental damage and human rights infringements (OECD, 2019[10]). In recent years there have been several cases in which economic activities with a high environmental impact have been the subject of legal disputes, clear example of liability risk.

- The landmark case of Sierra Club versus Morton revolved around the preservation of national parks and forests, highlighting the pressing need for environmental protection (OECD, 2019[10]).
- The Deepwater Horizon oil spill incident in 2010, which resulted in a financial hit of 65 billion USD for British Petroleum due to the extensive harm to natural resources and marine biodiversity, presents a compelling case (Bousso, 2018[11]).
- In March 2021 a global alliance of non-governmental organisations legally challenged the French retail giant Casino. The supermarket chain was sued over its purported neglect in averting deforestation in the Amazon and Cerrado regions of Brazil and Colombia, primarily caused by the cattle industry. The case also highlighted alleged human rights violations against indigenous peoples, bringing into sharp focus the wide-ranging implications of such liability risks (Clyde&Co, 2022[12]).

Furthermore, the *OECD Guidelines for Multinational Enterprises* laid out by the Organisation for Economic Co-operation and Development (OECD) indicate that a National Contact Point (NCP) can manage complaints, referred to as "specific instances", against corporations (OECD, 2019[10]). Submissions involving environmental concerns comprise 20 percent of all cases lodged to the NCPs since 2001, which equates to 88 cases. These include 38 cases from the mining and quarrying sector, and 7 from the agricultural, forestry, and fishing industries.

- On 4th May 2023, ClientEarth, an NGO, filed a complaint against the food company Cargill with the US OECD National Contact Point. The complaint highlights Cargill's alleged insufficient environmental and human rights due diligence in their Brazilian soy supply chain. Despite Cargill's established monitoring systems and commitments to local communities and Indigenous Peoples, ClientEarth argues that the company's due diligence is inadequate (Schappert, 2023[13]). This deficiency applies particularly to their sourcing of soy, involving a significant percentage of all their Brazilian soy purchases, from conservation-critical areas and through certain Brazilian ports. ClientEarth suggests that Cargill's practices contradict the OECD Guidelines for Multinational Enterprises and their specific guidance for responsible agricultural supply chains, which require companies to minimise their negative impact on forests and biodiversity (Schappert, 2023[13]).

The examples above illustrate the impact of nature-related liability risks on companies, but there is currently no evidence to support the possible subsequent financial risks which may materialise. However, a recent study by the Grantham Research Institute indicates that climate litigation action and unfavourable court rulings reduce firm value by -0.41 per cent on average, with a greater impact on companies which are considered to be ‘carbon majors’ (Sato et al., 2023[14]). Similar financial risks may materialise in response to nature-related liability action. Indeed, the locality of nature-related risks may enable greater attributability of impacts and hence lead to greater financial risks stemming from liability action than for climate change.

Case study, water scarcity and the economic impact of the mining sector in Chile

Introduction and rationale for the case study

Chile is one of Latin America’s leading industrial and agricultural exporters. Its central and northern regions hold economic and social significance due to the presence of agricultural and mining ventures. Chile’s mining industry is of substantial importance to the Chilean economy, contributing USD 317 billion or 15 percent of Chile’s GDP in 2021 and over 62 percent of the country’s total exports (International Trade Administration, 2022[15]). Mining is a strategic sector for the Chilean economy, who is set to play a pivotal role in the climate transition due to their rich deposits of lithium and copper, with around 26 percent of global supply for each metal extracted in Chile, respectively (USGS, 2023[16]). Additionally, recently approved royalties for mining regions means mining regions will receive additional revenues through modified taxes for large companies in the sector (Government of Chile, 2023[17]).

However, a prominent issue in these regions is the overutilisation of finite water resources (Toro et al., 2022[18]). The arid northern regions rank among the driest globally, and the operational demands of these industries place considerable pressure on local shared water resources (Oyarzún, 2011[19]). Among the multitude of industries that produce goods for human utility and consumption, agriculture stands as the most water-intensive, accounting for 70 percent of the total water usage. Other industries consume 20 percent, leaving 10 percent for direct human use.

Although the mining industry's water consumption is substantially lower compared to other sectors, notably agriculture, water scarcity presents threats to the viability of the sector and it continues to face persistent scrutiny from neighbouring communities (Toro et al., 2022[18]). In Chile, mining ranks as the fourth largest water consumer, accounting for 3 percent of the total water consumption across economic activities (Toro et al., 2022[18]). Over half of the nation's water used in mining (51 percent) is consumed in the Antofagasta region, nestled within the Atacama Desert, the country's driest locale (Aitken et al., 2016[20]). As a result, there is a concerted effort within the mining sector to preserve water and mitigate discharge, to mitigate the physical risks which may occur consequential of water scarcity.

These risks primarily arise due to the prevalence of mining deposits in arid regions where freshwater is a rare commodity, needing stringent regulatory intervention by government authorities in the water utilisation within mining operations. (Aitken et al., 2016[20]). Chile's General Water Directorate has extended the prohibition zones for water extraction, limiting water rights for mining firms (Toro et al., 2022[18]). Moreover, the country's authorities have decreed that large-scale mining projects will no longer receive authorisation to utilise water from aquifers. Consequently, the incorporation of seawater or desalinated water is being considered for new facilities, particularly in the country's northern region. These regions within the country are grappling with acute water shortage or excessive utilisation of water resources. Consequently, the Chilean copper sector has demonstrated noteworthy advancements in water efficiency (Stephen, 2017[21]). Hence, trade-offs exist between the economic benefits associated with mining activities and the potential risks posed by increased water scarcity.

Identification and Prioritisation

Direct Economic Activities

The relevant economic activities directly dependent and impacting water ecosystem services with a very high materiality rating, according to (ENCORE, 2023[22]) in Chile include:

- *Mining activities:* Mining, especially copper mining, is a primary industry in Chile. Water stress directly impacts this sector, raising operational costs and potentially affecting production volumes (Stephen, 2017[21]). Moreover, copper resources are more exposed to water-risk than lead, zinc, and nickel also at a global level (Stephen, 2017[21]).
- *Agriculture*: Chile has a vibrant agricultural sector, producing crops like grapes, avocados, and corn, with agriculture and related sectors representing 24 percent of total Chilean exports and 9 percent of GDP in 2021 (International Trade Administration, 2022[15]). Water stress can lead to lower crop yields, potentially harming farmers' incomes and increasing food prices.
- *Energy Production*: Many forms of energy production, especially hydroelectric power and biofuels, depend on the availability of water. In 2021 19 percent of Chile’s energy supply was sourced from hydropower and biofuels and waste (IEA, 2022[23]). Water stress could affect the generation of electricity, potentially leading to higher energy costs and reduced output.

Indirect Economic Activities

Many industries that rely on inputs from the sectors mentioned above could face indirect economic impacts, notable from supply chain disruptions due to water stress. For example, most notably manufacturers that depend on copper and lithium might face higher costs or shortages.

- *Building Construction*: plumbing, building plants, architecture, communications and electrical power constituted 28 percent of global copper demand in 2021 (Copper Alliance, 2022[24]).
- *Infrastructure*: power utility and telecommunications constituted 16 percent of global demand for copper in 2021 (Copper Alliance, 2022[24]).
- *Manufacturing*: industrial, transport and other activities represented 11 percent, 12 percent, and 32 percent of global copper demand in 2021, respectively (Copper Alliance, 2022[24]). Moreover, 80 percent of lithium demand stems from batteries, which are used in the manufacturing sectors for digital technologies and transport, with electric vehicles (EVs) (USGS, 2023[16]). Beyond mining, increased energy costs may impact the cost and production of manufacturing sectors.

Beyond the extraction of copper and lithium, other sectors which may be indirect impacts from water scarcity include:

- *Agri-food Sector:* The food and beverage industry, which relies heavily on agricultural products and fresh water, could face increased costs and potential product shortages.
- *Energy-intensive Manufacturing:* manufacturing industries which require substantial energy usage within their operations may face greater costs through sustained higher energy prices.

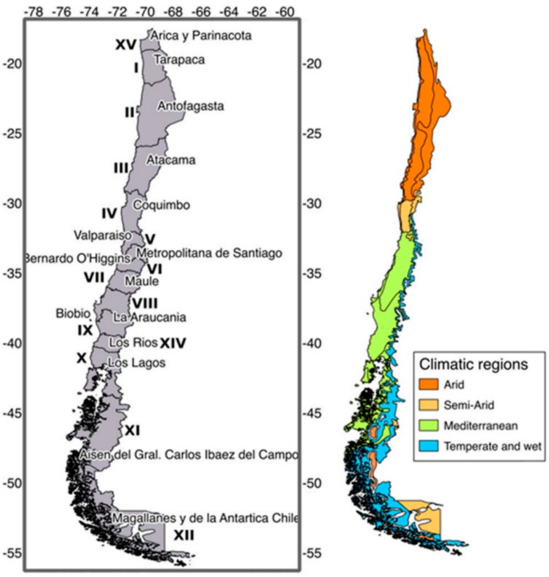
Geographic scope

Upon the identification of principal direct and indirect economic activities, the following section shows the potential risk sources, contingent on the geographic placement of these economic activities related to water demand. The focus pivots around the geographic region, the policy environment, and an assessment is made to delineate potential physical and transition risks, both within the domestic sphere and on an international scale.

Domestic Level

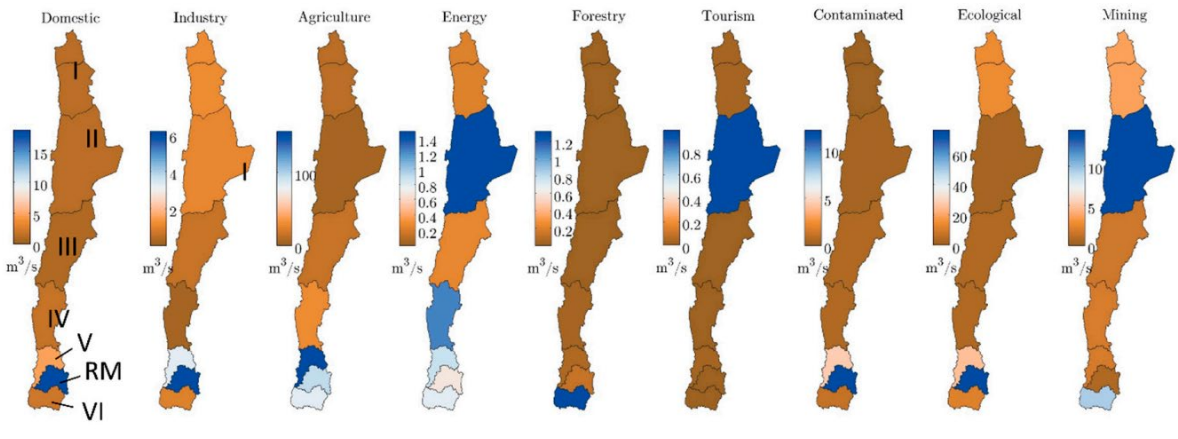
This section delves into the water availability identified by previous research in different regions of the Chile (see Figure 1). The Antofagasta region has a dry coastal area and a higher altitude area with the most rainfall. Surface water flow is minimal, with main flow predominantly from the river Loa watershed. As shown in Figure 2 below, there is significant water demand from the energy and mining sectors within the Antofagasta region. The Region of Coquimbo has a semi-arid climate with an agricultural industry significant to Chile. Also, the region is considered at high risk of climate change (Aitken et al., 2016[20]). Hence, tangible physical risks are present through the dependence of economic sectors on water ecosystem services. These risks may be exacerbated in future due to the rising demand of metals and the physical impacts from climate change. These physical risks are manifesting with the Chilean water crisis, which begun in 2010 and seen precipitation in central Chile below normal by an average of 20 to 45 percent (NASA, 2020[25]). These events have led to the rationing of water in the capital Santiago in 2022 (Reuters, 2022[26]).

Figure 1. Chilean administrative regions and the climatic regions of Chile



Source: data from *IDE Catálogo Nacional de Información. Infraestructura de Datos Geoespaciales* (IDE, 2015[27]) elaborated by Aitken et al. (2016[20]).

Figure 2. The water demand of each sector by region in Chile



Source: data from IDE, Catálogo Nacional de Información. Infraestructura de Datos Geoespaciales (2015) elaborated by Aitken et al. (2016[20]).

The policy environment governing water ecosystem services in Chile is marked by its unique blend of public regulation and market-based approaches (Oyarzún, 2011[19]). Chile's Water Code, established in 1981, is distinctive in its privatisation of water rights. It allocates water resources through a system of tradable water usage rights, encouraging efficient usage through market mechanisms (Aitken et al., 2016[20]). In response to the increasing threat to water security, Chile has developed its Long-Term Climate Strategy, which contains targets to reduce the mining sector's water usage by 2030 and 2050, as well as minimise the environmental effects of mining activity (Government of Chile, 2021[28]).Additionally, in 2022 the Chilean Government updated the water code which encompasses four key areas: (i) the recognition of human rights for water and sanitation; (ii) the consideration of ecosystem function regarding water ecosystem services; (iii) the promotion of sustainable production and water efficiency; and (iv) enhanced governance and territorial management. Consequently, all watersheds should have a Strategic Water Management Plan, including better information with a long-term view on current and future water availability (Ministerio del Interior y Seguridad Pública, 2022[29]). These policy measurements are likely to reduce the physical risks for sectors dependent on water ecosystem services. However, these policies may also induce transition risks through higher prices or a reduction in output due to restrictions on water usage.

Global level

The implications of nature-related risks in Chile propagate beyond the country's borders, influencing global economic landscapes, through global value chains. Particularly notable are the sectors of mining and agriculture, in which Chile's prominent role on the international stage signifies substantial global economic repercussions (Stephen, 2017[21]). Chile's mining sector, particularly its significant copper production, plays a pivotal role in global supply chains. Any physical or transition risk leading to disruption or curtailment of operations in Chile could resonate across industries worldwide (Toro et al., 2022[18]). In 2021, copper ore exports from Chile included to China (USD 29.7bn), Japan (USD 4.45bn), South Korea (USD 1.03bn), India (USD 888m), and Spain (USD 608m). Depending on the ability of firms to pass on the increased costs due to an increase copper prices globally from water scarcity in Chile, these countries or industries reliant on copper such as electronics, construction, and renewable energy may be significantly impacted (Stephen, 2017[21]).

Chile's role in global value chains, especially within indirect economic sectors like manufacturing and services, implicates that disturbances due to water stress may echo across international markets. Imported risks such as volatile commodity prices, fluctuating market demands, and stringent regulatory frameworks can undermine Chile's contribution to these value chains, leading to potential economic and financial instability (Aitken et al., 2016[20]).

Economic Impacts of water stress on Chilean mining sector

Microeconomics impacts

Microeconomic impacts typically involve effects at the level of individual businesses, households, or consumers. Here are some potential microeconomic impacts of water stress on the mining sector in Chile:

- **Operational Costs**: For mining companies, water stress can lead to higher operational costs. Water is a crucial input for mining processes, and scarcity can make sourcing, treating, and managing this resource more expensive. Increased costs can reduce a company's profit margins and potentially affect its competitiveness (Toro et al., 2022[18]). If water stress leads to higher costs or reduced production in the mining sector, this could potentially affect the prices of goods made from mined materials. This could have knock-on effects for the subsequent value chain which are dependent of these mined materials as inputs, both within Chile and globally (Villar-Navascués and Fragkou, 2021[30]).
- **Rising Capital Expenditure**: To mitigate water scarcity, mining companies might need to invest in alternative water sources, such as desalination plants or wastewater recycling facilities. These investments can be capital-intensive and may affect a company's financial performance and investment decisions.
- **Production**: If water becomes too scarce or expensive, mining companies might need to adjust their production decisions. This could involve reducing output, temporarily shutting down operations, or even closing mines permanently. These decisions could affect a company's revenues and market share globally (Villar-Navascués and Fragkou, 2021[30]) (Toro et al., 2022[18]). Regions where water scarcity persists may become financial unviable to continue operations, for example agricultural land, which may lead to a physical stranding of assets.
- **Increasing investments risks**: for investors in mining companies, water stress could increase risks. Companies facing higher costs or production uncertainties due to water scarcity might see their share prices affected, leading to potential losses for investors (Aitken et al., 2016[20]).
- **Local Community conflicts**: At the household level, mining operations can affect local water supplies, potentially leading to higher water costs or reduced access to water for residents. This can affect household budgets and increase litigation risks for firms. Additionally, if water scarcity becomes a persistent issue, this may impact the asset valuation of real estate

Macroeconomics impacts

The macroeconomic impacts of water stress on the mining sector in Chile could be substantial given the significant role mining, particularly copper mining, plays in the Chilean economy. Here are some potential macroeconomic impacts:

- **Gross Domestic Product (GDP) decline**: If water stress leads to reduced mining output, this could directly decrease the contribution of the mining sector to Chile's GDP. Moreover, indirect effects on sectors that rely on mining (like manufacturing and services) could further impact the country's overall economic output given also the relevance of mining sector for the country (Aitken et al., 2016[20]) and (Stephen, 2017[21]). Over the longer term, water stress could influence the sustainability of Chile's economic growth. If scarce water resources are not managed sustainably, it could constrain the country's economic development and potentially lead to greater economic volatility.

- **Export Revenues and Currency**: Chile is the world's largest exporter of copper, so any water stress-induced disruptions in the mining sector could significantly affect the country's export revenues. This could, in turn, impact the trade balance and potentially the value of the Chilean peso.
- **Government Revenues**: The Chilean government derives substantial revenue from the mining sector in the form of taxes, royalties, and state ownership of some mining companies. Reduced profitability or production in the mining sector due to water stress could therefore decrease government revenues, potentially affecting public spending and fiscal balance (Stephen, 2017[21]).
- **Investment**: Water stress could affect investment decisions in the mining sector. If Chile is seen as a high-risk location due to water scarcity, it could deter domestic and foreign investment, not only in mining but potentially in other sectors as well.
- **Inflation**: If water stress leads to increased costs or reduced production in the mining sector, this could potentially affect the prices of goods, leading to inflationary pressures. This effect could be particularly significant given the importance of mined materials in many industries (Villar-Navascués and Fragkou, 2021[30]).
- **Employment and Regional Economies**: If mines reduce production or shut down due to water stress, it could lead to job losses, affecting unemployment levels and potentially causing economic hardship in mining-dependent regions.

In conclusion, water stress could have significant microeconomic and macroeconomic impacts on the Chilean economy, given the importance of the mining sector. These impacts could affect a wide range of economic indicators and potentially influence the country's long-term economic trajectory.

Nexus with climate change and other risks

The economic risks detailed in this section may exacerbate, or be exacerbated by, alternative sources of risk and lead to a greater magnitude of impact. In the case of the Chilean mining sector, the climate transition will increase the demand for copper and lithium 3- and 42-fold, respectively, under a Sustainable Development Scenario (IEA, 2021[31]). This significant increase in demand may place greater demands on the water ecosystem services in Chile, heightening physical risks, as well as demand-induced pressures on commodity prices. This increase in demand is already materialising, with the value of global trade for lithium increasing 438 percent between 2017-2019 compared to 2007-2009 (Kowalski and Legendre, 2023[32]) Additionally, the global incident of export restrictions on raw materials increase more than five-fold in the last decade, primarily through export taxes (Kowalski and Legendre, 2023[32]). The increase in trade frictions and demand for these materials contributes to their costs and may lead to sustained higher prices, which in turn may interact with and magnify the risks stemming from water scarcity.

Financial risks from water scarcity

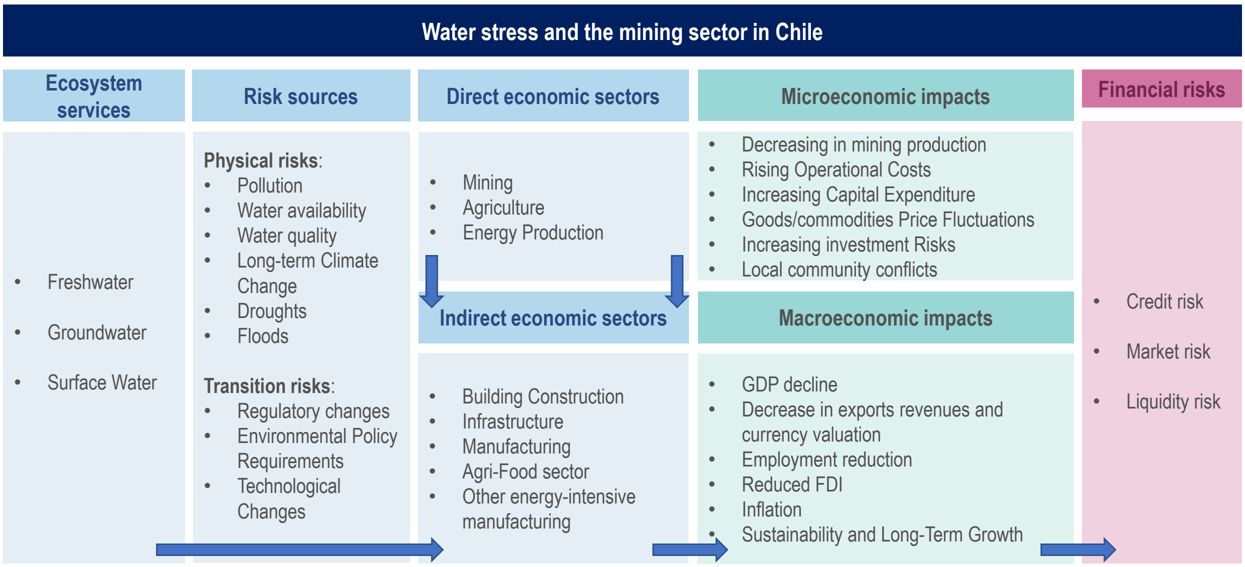
Subsequent financial risks may materialise from the impact of water scarcity on the Chilean mining sector as well as other direct and indirectly affected sectors.

- **Credit Risk**: The mining sector, as well as sectors which require mined materials for inputs, may be affected by water stress through reduced profitability. This reduction in profitability may stem from an increase in operational costs, including increased expenditure to mitigate risks or higher input costs, or a reduction in output due to a disruption in output. Reduced profitability may lead to credit risks if companies are unable to meet the financial obligations to debtholders or other financial actors.
- **Market risk**: The materialisation of these risks could also translate to increases in market prices volatility for listed companies, affecting market valuations of mining companies. Depending on the extent of these impacts, at micro-financial level, exposed financial institutions could be affected by

changes in market valuations due to volatility in equity prices and derivative instruments. At a macro-financial level, sudden repricing of sectoral valuations in response to acute nature-related events may lead to more systemic market risks for financial institutions.

- **Liquidity Risk:** Abrupt reductions in supply of traded commodities, such as copper and lithium, will likely induce short-term price volatility, with implications for commodity and derivative markets. These can lead to liquidity and funding risks for financial institutions with significant market positions. For example, the recent supply-side shock for nickel, due to the invasion of Ukraine, led to an unprecedented 250 percent price spike and the suspension of trading on the London Metal Exchange (LME) (Burton, Farchy and Cang, 2022[33]).

Figure 3. Links from water ecosystem services to economic sectors and nature-related financial risks



Source: OECD authors' illustration.

Case study, economic and financial implications of deforestation in Indonesia

Introduction and rationale for the case study

According to IPBES, changes in land use (i.e. deforestation) is the major driver of global biodiversity loss (IPBES, 2019[4]). Research suggests that the world has experienced a pattern of declining global forestland, with approximately 178 hectares of forest estimated to have been lost since 1990 (FAO, 2020[34]). As discussed through the document, this scenario could stem risks for the financial sector and financial stability.

Covering one of the largest areas of tropical rainforest, Indonesia's forests are not only essential for global environmental integrity but also are a source of significant provisioning and regulating ecosystem services (UNORCID, 2015[35]). Nevertheless, between 2000 and 2013, Indonesia was the country with the largest deforestation rate in the world (Hansen et al., 2013[36]).The generalised loss of forests through the national territory implied an increased likelihood of physical risks, which could interrupt the provisioning of ecosystem services, among other consequences. Therefore, since 2011, the Indonesian government has prioritised the introduction of several policy measures to reduce deforestation rates. Such measures include a moratorium on logging concessions and licences, following Presidential Instruction No. 10/2011 (Murdiyarso et al., 2011[37]).

While the government measures slowed deforestation rates through a strong policy response, by 2016, Indonesia still had one of the highest rates of primary forest loss in the tropics; the country lost almost one million hectares of primary forest loss in 2016 (Austin et al., 2019[38]) (Jong, 2023[39]). Even though deforestation is attributed to myriad of reasons including the extension of agriculture and fires, large-scale palm oil plantations are one of the main drivers of forest loss in the country (Austin et al., 2019[38]). For this reason, the government has followed similar policy responses as in previous occasions, introducing moratoria to exploitation contracts, as well as more regulations to control the palm oil trade (Reuters, 2021[40]; Ministry of Environment and Forestry, 2020[41]).

The palm oil industry represents around 3.5 percent of the Indonesian GDP and around 60 percent of global palm oil (Indonesian Palm Oil Association, 2021[42]). Indonesia is the largest palm oil exporter of the world (USDA, 2023[43]). This product is highly demanded for food, cosmetic and energy purposes. Its demand, however, increased after Russia's war of aggression against Ukraine, which caused a shortage of sunflower oil (Bloomberg, 2022[44]). Hence, there have been difficulties meeting the global demand of vegetable oils in the market, causing disruptions in global value chains and increases in prices (Roswell, 2022[45]). Given the relevance of the Indonesian rainforests for environmental integrity, the role of palm oil industry in the loss of forests, as well as the relevance of this industry for international markets, this case study aims to delve into the extent to which the financial sector is exposed to nature-related risks based on the Indonesian case.

Identification and Prioritisation

Direct Economic Activities

The relevant economic activities that are directly dependent and impact Indonesian forests with a very high materiality rating include (ENCORE, 2023[22]):

- *Agriculture*: Agriculture plays a significant role in Indonesia's economy. It is estimated that primary agriculture represented 13.7 percent of Indonesia's GDP in 2020. This economic activity includes close to 29 percent of the Indonesian workforce (The World Bank, 2022[46]). The country is also a major global producer and exporter of various agricultural products including palm oil, rubber, wood and food products (World Integrated Trade Solution, 2023[47]). Agriculture-related economic activities are highly dependent on water ecosystem services, as well as regulating ecosystem services such as pollination, provided by local species and habitats. Simultaneously, these activities also impact land ecosystem services through deforestation and soil degradation, as well as water ecosystem services through extensive water demand and water pollution.

Indirect Economic Activities

Many industries that rely on inputs from the agriculture sector could face indirect economic impacts, notable from supply chain disruptions. For example, most notably sectors that depend on palm oil might face higher costs or shortages:

- *Agri-food Sector:* The food and beverage industry, which relies heavily on agricultural products and fresh water, could face increased costs and potential product shortages. Palm oil has become particularly relevant with this regard. As mentioned above, Russia's aggression war against Ukraine has caused a shortage of global sunflower oil, meaning that the agri-food sector is particularly reliant on palm oil, given the limited number of substitute products (Bloomberg, 2022[44]). It is calculated that 80 percent of global palm oil production is used for food purposes (Ministère de la transition écologique et de la cohésion des territoires, 2022[48]).
- *Cosmetic sector*: The cosmetic sector relies on various agricultural products, including palm oil, as raw materials for production. A shortage on agriculture production could translate into increased prices for cosmetic products. As of 2019, around 70 percent of personal care items contained palm oil derivatives (Tullis, 2019[49]).
- *Energy sector*: Agriculture was long ago recognised as a sustainable source of energy (FAO, 2000[50]). Agricultural crops such as sugar cane, palm and corn can be grown specifically for bioenergy purposes, which are aimed to act as alternatives to fossil fuels. In Europe, for instance, 65 percent of palm oil imports were used for energy purposes (Transport and Environment, 2019[51]). Hence, disruptions in agriculture may also translate into increased energy costs, which may also impact the cost and production of manufacturing sectors.

Geographic scope

After identifying the main direct and indirect economic activities, the following section shows the potential risk sources based on the geographic location of these economic activities related to agriculture in Indonesia. The underlying analysis focuses on the palm oil industry and examines different dimensions on possible sources of risks.

Domestic level

Between 2000 and 2014, Indonesia experienced an annual deforestation of approximately 1.3 million hectares, with almost 40 percent of deforestation taking place in primary forests (Global Forest Watch, 2017[52]). In relation to primary forests, Indonesia has lost nearly 10 million hectares of these (Shareen, 2022[53]). While deforestation has been a general through its territory, a significant portion of forest loss has occurred in Sumatra and Kalimatan, the two Indonesian islands with the largest forest area (The World Bank, 2021[54]; Global Forest Watch, 2017[52]). Thus, physical risks emerge as economic sectors rely on forests' provisioning and regulating services. While Indonesian deforestation and palm oil plantations have slowed down as a result of multiple factors including a strong policy response, the impacts of forest loss remain insufficiently quantified (Wageningen University & Research, 2022[55]). Therefore, there are still chances that physical risks may be exacerbated in the future due to the rising global demand of palm oil and the physical impacts from climate change.

As mentioned previously, the Indonesian government has opted for a strong policy response to decrease deforestation rates through the country, as well as carbon emissions caused by human-started fires to clear forests and peatlands for new palm crops. Measures have included moratoria on forest exploitation, which have introduced prohibitions on new palm oil exploitation permits, as well as revisiting existing palm oil permits (Environmental Investigation Agency, 2019[56]). While these policies are likely to reduce the likelihood of physical risks for sectors dependent on Indonesian forests, they also represent a source of transition risks for the financial sector. As the demand for palm oil increases, which translates into higher prices for palm oil and accordingly, stronger incentives for investments allocated to this industry, stricter regulations and increased scrutiny on palm oil industry could be expected (transition risks).

Global level

Additional sources of risk can be identified at the global level related to deforestation, agriculture and the palm oil in Indonesia. From the viewpoint of physical risks, it is important to highlight that Indonesia's forests and peatlands are one of the world's largest carbon sinks (Greenpeace, n.d.[57]). Hence, deforestation in the country may accelerate climate change, which intensifies global acute and chronic physical risks such as droughts that could translate into losses to the financial sector.

Countries around the world have shown concerns about the environmental implications related to palm oil. For instance, the European Union has taken regulatory measures on palm oil imports after its conclusion that the palm oil industry causes high rates of deforestation (Reuters, 2023[58]). Likewise, there is a global emergence of requirements on palm oil sustainability for environmental protection, which has decreased profits for palm oil producers, especially small farmers (IISD, 2023[59]). These cases illustrate that the palm oil industry is susceptible to additional transition risks given global trends on policy changes concerning sustainability practices for this sector.

It is relevant to highlight Indonesia's relevance in global value chains, especially within indirect economic sectors such cosmetics, agro-food and energy sector. Indonesia produces around 60 percent of global palm oil (USDA, 2023[43]). Disruptions in palm oil supply, arising from either physical or transition risks, have the potential to affect international markets, leading to potential economic and financial instability.

Economic Impacts

Microeconomics impacts

- **Decrease in agricultural outputs**: In the medium-to-long term agricultural companies could be affected by the reduction in ecosystem services such as soil quality, water and climate regulation linked to deforestation. These crucial inputs for agricultural processes might affect the total output of existing fields, reducing the quantity and quality of agricultural products.
- **Operational Costs**: For agricultural companies, risks linked to water quality, droughts and diseases can lead to higher operational costs. Deforestation could lead to worsening conditions and increase the risk of physical events. Increased costs can reduce a company's profit margins and potentially affect its competitiveness (Toro et al., 2022[18]). Additionally, regulation and transition risk can also lead to changes in business practices which might affect how agricultural companies operate.
- **Goods price fluctuations:** Possible reduction in the quality or quantity of agricultural products might have consequences for a range of industries, particularly for the agri-food and cosmetic industries. The food and beverage industry relies heavily on agricultural products and could face increased costs and potential product shortages, leading to the possibility of price hikes.
- **Local Community conflicts**: At the household level, deforestation and possible negative consequences can affect local communities. This can affect household budgets and increase litigation risks for firms.

Macroeconomics impacts

- **Gross Domestic Product (GDP) decline**: If risks lead to reduced agricultural output, this could directly decrease the contribution of the agriculture sector to Indonesia's GDP. Moreover, indirect effects on sectors that rely on agriculture could further impact the country's overall economic output with effects beyond its national borders.
- **Government Revenues**: The Indonesian government derives substantial revenue from the palm oil sector. Reduced profitability or production in the agriculture sector due to several risks could therefore decrease government revenues, potentially affecting public spending and fiscal balance (Stephen, 2017[21]).
- **Inflation**: If risks related to agriculture lead to increased costs or reduced production in the agriculture sector, this could potentially affect the prices of goods, leading to inflationary pressures. This effect could be particularly significant given the importance the agri-food, cosmetics and energy industries.
- **Employment and Regional Economies**: Given the palm oil production is located in many areas of Indonesia, including more rural areas, reduction in production or shut down due to risks could lead to job losses, affecting unemployment levels and potentially causing economic hardship in agriculture-dependent regions.

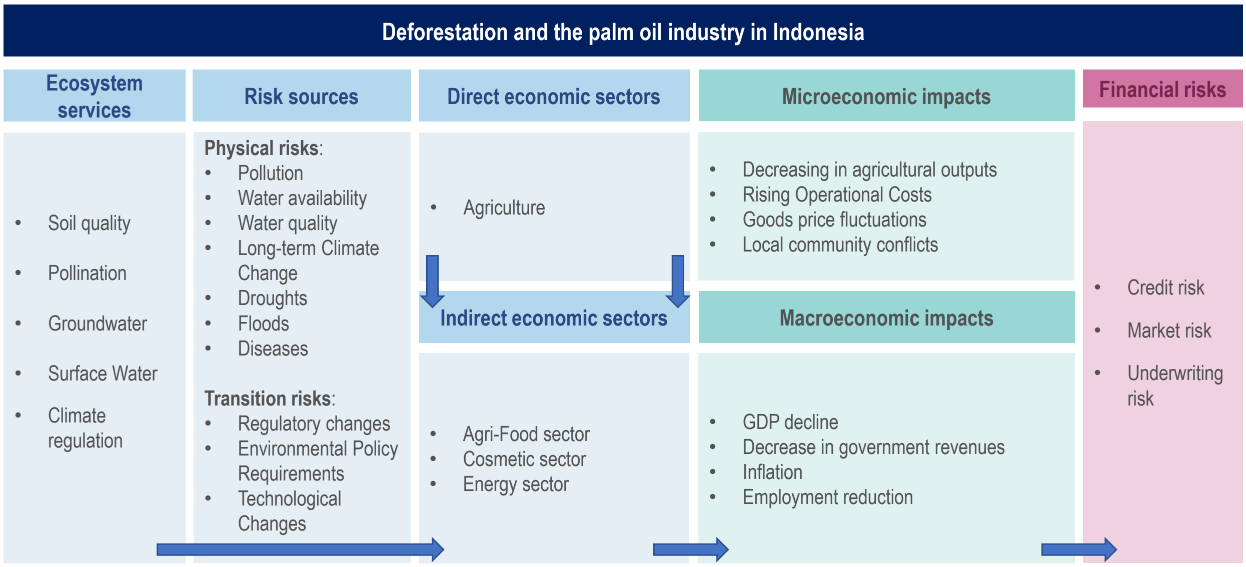
In conclusion, deforestation and other leading risks could have significant microeconomic and macroeconomic impacts on the Indonesian economy, given the importance of the palm oil and general agricultural sector. These impacts could affect a wide range of economic indicators and potentially influence the country's long-term economic trajectory.

Financial risks from deforestation

Subsequent financial risks may materialise from the impact of deforestation on the Indonesian agricultural sector as well as other direct and indirectly affected sectors.

- **Credit Risk**: The agriculture sector, as well as sectors which require agricultural outputs as inputs, may be affected by a number of risks through reduced profitability. This reduction in profitability may stem from an increase in operational costs, including increased expenditure to mitigate risks or higher input costs, or a reduction in output due to a disruption in output. Reduced profitability may lead to credit risks if companies are unable to meet the financial obligations to debtholders or other financial actors.
- **Market risk**: The materialisation of these risks could also translate to increases in market prices volatility for listed companies, affecting market valuations of agricultural companies. Depending on the extent of these impacts, at micro-financial level, exposed financial institutions could be affected by changes in market valuations due to volatility in equity prices and derivative instruments. At a macro-financial level, sudden repricing of sectoral valuations in response to acute nature-related events may lead to more systemic market risks for financial institutions.
- **Underwriting risk**: Insurers of agricultural outputs may experience nature-related financial risks through their investments and liabilities related to transition and physical risks (EIOPA, 2023[60]) as well as the possibility of inaccurate assessment of nature risks. This might lead to refusal to insure agricultural companies if the risk is deemed too high, leading to increased costs for the agriculture sector.

Figure 4. Links from ecosystem services to economic sectors and nature-related financial risks



Source: OECD authors' illustration.

Annex 4: Application to commercial banks

The annex examines the applicability of the methodological framework for commercial banks, regarding the identification, prioritisation, and assessment of nature-related financial risks. In particular, the annex identifies the chapters of the framework which are directly applicable for commercial banks, and chapters where further adaptation is necessary. Chapters 1, 2, and 3 in the main report are directly applicable for commercial banks with a slight adjustment in scope to focus on risks relevant for their portfolios and individual exposures, rather than the macroeconomic implications of nature-related risks.

With regards to Chapter 2, the proposed risk identification and prioritisation approach aims to serve as a complementary tool to the TNFD's 'LEAP' approach. The LEAP (Locate, Evaluate, Assess and Prepare) approach has been designed for use by companies and financial institutions of all sizes, sectors and geographies to identify and assess their nature-related issues (dependencies, impacts, risks and opportunities). It involves four phases, with each phase consisting of several components. The four phases are: (i) *Locate* your interface with nature; (ii) *Evaluate* your dependencies and impacts on nature; (iii) *Assess* your nature-related risks and opportunities; and (iv) *Prepare* to respond to, and report on, material nature-related issues, aligned with the TNFD's recommended disclosures.

As shown in in

Figure 5, both approaches are aligned in that they share common elements in terms of their contents. This will support harmonisation and consistency of international guidance on how to identify, assess and address nature-related risks. It is important to note that using both approaches would provide a more comprehensive understanding of a commercial bank's exposure to nature-related risks, given that each approach differ in focus and degree on certain aspects. For instance, the LEAP approach provides the outputs needed to allow for nature-related disclosure (aligned with the TNFD recommendations), while the presented risk identification and prioritisation approach explores in further depth use of nature scenarios as a relevant tool to forecast relevant nature-related risks.

The financial risk transmission channels outlined in Chapter 4 of the report are also directly relevant for commercial banks to understand the financial risks stemming from nature-related events. The possibility of financial risk contagion is relevant insofar as these risks may directly affect the balance sheet and operations of the commercial bank. The supervisory considerations outlined in Chapter 5 of the report are less directly applicable for commercial banks. However, commercial banks may want to consider how nature-related risks may be incorporated into their own risk management practices and how regulatory developments may affect their activities.

Figure 5. The risk identification and prioritisation approach's alignment with the TNFD's LEAP approach

Phase	Alignment with the TNFD's LEAP Approach			
Impacts and Dependencies	L2 Nature interface	E2 ID of dependencies and impacts	E3 Dependency analysis	E4 Impact analysis
Economic Sector	L1 Span of the business model and value chain	L2 Nature interface	L4 Sector identification	A1 Risks and opportunity identification
Ecosystem Service	L2 Nature interface	L3 Priority location identification	E1 ID of relevant environmental assets and ecosystem services	A1 Risks and opportunity identification

Source: OECD authors' illustration.