

ENVIRONMENT DIRECTORATE

**WATERED DOWN? INVESTIGATING THE FINANCIAL MATERIALITY OF WATER-RELATED RISKS IN THE FINANCIAL SYSTEM
ENVIRONMENT WORKING PAPER NO. 224.**

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Abstract

Water-related risks are intrinsically linked to both climate and nature challenges and can be closely tied to socio-economic challenges, such as poverty, food security, and domestic and international conflicts. There is increasing evidence that water-related risks are financially material across actors in the financial system, and further still, that there may be important implications for financial stability. However, a review of current practices indicates that these risks are not fully captured by current approaches to assessing risk.

This working paper explores how the financial sector understands the concept of financial materiality as a lever for decision making on water-related climate and nature risks. The paper also looks at how regulatory and supervisory guidance considers water in the context of climate and nature risks, and finally how sustainable finance tools and initiatives can support market participants in gaining an improved understanding of water-related risks.

Keywords: water, water finance, water-related risks, finance and investment, economics, financial materiality

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Résumé

Les risques liés à l'eau sont indissociables des enjeux du climat et de la nature et peuvent être étroitement liés à des défis socioéconomiques comme la pauvreté, la sécurité alimentaire et les conflits intérieurs et internationaux. Leur importance financière pour l'ensemble des acteurs du système financier et, plus encore, les lourdes conséquences qu'elles peuvent avoir pour la stabilité financière semblent de plus en plus avérées. Pourtant, il ressort d'une analyse des pratiques en vigueur que les approches actuelles d'évaluation des risques n'en tiennent pas pleinement compte.

Ce document de travail examine comment le secteur financier appréhende le concept d'importance financière en tant que levier de décision concernant les risques liés à l'eau et les risques naturels. Il étudie en outre comment les orientations réglementaires et prudentielles envisagent l'eau dans le contexte des risques climatiques et naturels et, pour finir, en quoi des outils et initiatives de financement durable peuvent aider les acteurs du marché à mieux comprendre les risques liés à l'eau.

Mots clés : eau, financement de l'eau, risques liés à l'eau, finance et investissement, économie, importance financière

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There is increasing evidence that water-related risks are financially material across actors in the financial system, and further still, that there may be important implications for financial stability. However, a review of current practices indicates that these risks are not fully captured by current approaches to assessing or managing risk in the financial system. This working paper aims to support both the water and finance community in exploring how the financial sector understands the concept of financial materiality as a lever for decision making on water-related climate and nature risks.

This report is an output of the OECD Environment Policy Committee (EPOC) and its Working Party on Working Party on Biodiversity, Water and Ecosystems (WPBWE). It is authored by Lylah Davies of the OECD's Environment Directorate and Mireille Martini of the Climate Bonds Initiative. The work was conducted under supervision of Xavier Leflaive, former lead of the Water team, and Walid Oueslati, Head of the Climate Biodiversity and Water Division of the OECD's Environment Directorate. The authors thank Ines Reale, OECD, for administrative support.

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The responsibility for the content of this publication lies with the authors.

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Executive summary

Water-related risks, including risk of too much, too little and polluted water, and disruption to the freshwater systems, are intrinsically linked to both climate and nature challenges. These risks can pose a significant risk to economies and societies today and in the future and can be directly linked to greenhouse gas emissions, changing weather patterns and biodiversity loss (IPBES, 2019^[1]) (IPCC, 2022^[2]).

Increasing evidence shows that anthropogenic pressures are pushing the Earth's water cycle off balance, with consequences on the reliability of rainfall (Mazzucato et al., 2023^[3]). By 2050, the number of people exposed to floods is expected to grow from the current 1.2 billion to 1.6 billion (UN, 2020^[4]) and 52% of the world's population is projected to live in water-stressed regions (Colin et al., 2018^[5]). This can only exacerbate socio-economic challenges, such as poverty, food insecurity, and domestic and international conflicts.

The financial sector has an important role in protecting the environment and has already become a key arena for climate change through commitments set under the Paris Agreement adopted at United Nations (UN) Climate Change Conference of the Parties (COP 21). More tangible action is now needed to mobilise finance towards nature goals, of which water is also a key element. This message has been strengthened since the 15th Conference of the Parties to the Convention on Biological Diversity (COP15), where countries adopted the Kunming-Montreal Global Biodiversity Framework, to halt and reverse biodiversity loss by 2030.

This working paper explores how the financial sector understands the concept of financial materiality as a lever for decision making on water-related climate and nature risks, and through which channels these risks are transmitted to the financial system. The paper also explores how water-related risks are financially material in the economy, as well as the financial system's current understanding of this materiality. In the following sections, the paper looks at how regulatory and supervisory guidance considers water in the context of climate and nature risks, and finally how sustainable finance tools and initiatives can support market participants in gaining an improved understanding of risks.

This paper finds that there is clear evidence that water-related risks are financially material across actors in the financial system, and that there may be important implications for financial stability, as evidenced by recent central bank studies. The topic of financial materiality of water-related risks has evolved rapidly in the last few years, however, a review of current practices indicates that these risks are not fully captured by current approaches to assessing or managing risk (OECD, 2021^[6]). There is now growing recognition that the financial sector is materially exposed to water-related risks and this exposure is not fully understood by central banks and financial institutions (Coloia and Jansen, 2021^[7]; ECB, 2022^[8]).

While prudential regulation does not explicitly cover water-related risk, supervisory guidance, notably under the guidance of the Network for Greening the Financial System (NGFS) is starting to lay building blocks for management of climate risks, notably through the development of climate scenarios for banks and supervisors. More recently, this work has started to address nature risks, with the development of a conceptual framework for understanding nature-related financial risk and new work on nature scenarios is upcoming. Similarly, nature-related disclosure is still in much earlier stages than climate disclosure. But

increasing the quantity and comparability of data on impacts and dependencies on water resources, will be pivotal to supporting central banks, investors, lenders and corporates in the identification of risks and opportunities linked to water. Already, sustainable finance initiatives and tools, while imperfect, provide an increasing number of options for investors to start assessing financial and impact materiality of water-related risk investments, and use this information to manage risks and drive change where needed. The sustainable finance landscape needs to evolve rapidly to capture both climate and nature dimensions of investments with impacts and dependencies on water, and increasing availability and comparability of data will be important in this regard.

Through both climate and nature discussions, it will be critical to continue strengthening the financial sector's understanding of the role of water. When managed correctly, water can have a crucial role in improving resilience to climate change, preserving nature, supporting economic activities and enabling prosperous societies. Conversely, too much, too little or polluted water or disruptions to freshwater systems can have a detrimental role in nature degradation and loss, contribute to climate change and exacerbate climate impacts. Equally, these risks can directly or indirectly disrupt economic activities and erode health and wellbeing. This points to an important need for strong collaboration between the environment and the finance communities, to improve collective understanding of how water-related risks translate into financial risk, and to develop the necessary tools and data to assess financial materiality and environmental impacts.

Abbreviations and acronyms

BES	Biodiversity and Ecosystem Services
CRCI	Cash Return on Capital Invested
CSRD	Corporate Sustainability Reporting Directive
DNSH	Do No Significant Harm
ENCORE	Exploring Natural Capital Opportunities Risks and Exposure
EFRAG	European Financial Reporting Advisory Group
FSB	Financial Stability Board
GRAS	Global Risk Assessment Services
GHG	Greenhouse gas emission
IPR	Inevitable Policy Response
LCA	Life Cycle Assessments
LCI	Life Cycle Inventory
MFID	Markets in Financial Instruments Directive
MRV	Measurement, Reporting and Verification
NCFA	Natural Capital Finance Alliance
NGFS	Network for Greening the Financial System
UN PRI	United Nations Principles for Responsible Investment
SBT, SBTi, SBTN	Science-Based Targets; Science-Based Targets initiative; Science-Based Targets for Nature
SUDS	Sustainable Urban Drainage Systems
SAR	Synthetic Aperture Radar
ARD	Analysis Ready Data
TNFD	Taskforce on Nature related Financial Disclosure
UN	United Nations
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNEP-FI	United Nations Environment Programme Finance Initiative

Introduction

While water is the most abundant liquid on Earth, only a small share of it is freshwater, which is irregularly distributed over different continents. Seasonal climatic variation, climate change and intensive exploitation cause variations in freshwater volumes over time, which can have drastic impacts at local or regional scales (UNESCO, 2022^[9]).

Water is intrinsically linked to both climate and nature challenges. There is a growing body of research on physical climate risks, not least by the Intergovernmental Panel on Climate Change (IPCC) that already identifies with high confidence, the widespread, pervasive impacts of water-related events on biodiversity, ecosystems, human health, food security, livelihoods and infrastructure, amongst others (IPCC, 2023^[10]).

The hydrological cycle is one of the most important channels through which climate impacts manifest, namely through drought and increase in heavy precipitation, or extreme weather events, including flooding and storms. Climate change is an increasing pressure on water systems and 90% of all natural disasters are water related (UNEP, 2023^[11]). By 2050, the number of people exposed to floods is expected to grow from the current 1.2 billion to 1.6 billion (UN, 2020^[4]) and 52% of the world's population is projected to live in water-stressed regions (Colin et al., 2018^[5]).

At the same time, nature, which encompasses all physical aspects of the natural world, including both biotic and abiotic elements, plays a significant role in stabilising greenhouse gas (GHG) emissions and increasing resilience climate change impacts. Water is essential to this process, notably through wetlands, which naturally absorb and store carbon, buffer coastlines from extreme weather and reduce the impacts and droughts (Ramsar, 2019^[12]).

Yet, economic activities are putting increasing pressure on freshwater resources and growing evidence shows that anthropogenic pressures are shifting the Earth's water cycle out of balance, threatening to undermine the reliability of rainfall itself (Mazzucato et al., 2023^[3]). Water demand is increasing across the globe, driven by use patterns in developed economies and growing population and economic activity in developing and emerging economies. This increasing demand creates competition for existing resources whilst also contributing to increased pollution and depletion of local freshwater sources.

Water-related risks, including risk of too much, too little and polluted water, and disruption to the freshwater systems, can therefore have a detrimental role in nature degradation and loss, and in contributing to climate change and its impacts. It follows that water-related risks also have important consequences for economies and societies, today and in the future and effective management of water resources is crucial for supporting sustainable growth and development.

Water stress is already affecting businesses across sectors, and particularly those sectors that heavily rely on water, such as agriculture, energy production, and mining and materials (CDP, 2022^[13]). Variations in freshwater volumes can already be seen through shrinking lakes, such as Lake Chad and the Aral Sea (Wurtsbaugh, Miller and Null, 2017^[14]), the disappearance of springs and declining flows in rivers, including the Yellow River, the Ganges, and Rio Grande (Shi et al., 2019^[15]), and steadily falling groundwater levels in intensively exploited aquifer systems such as in the North China Plain and the Central Valley in California (Shamsudduha and Taylor, 2020^[16]). Even where water has been considered a plentiful renewable

resource, there is increasing stress on supply, with countries such as France imposing restrictions to avoid a water crisis (Hernandez, 2023^[17]).

Recent events have also highlighted how global supply chain can be exposed to extreme weather events. For example, as a key production hub for global automobile manufacturers, prolonged flooding in Thailand in 2011 caused disruptions in the supply chains for the automotive industry, notably affecting Honda, Toyota and Nissan (Haraguchi and Lall, 2015^[18]). Likewise, drought in 2021 in Chinese Taipei, a key hub in the global technology supply chain for advanced semiconductors, caused disruptions to chip manufacturing, which impacted global giants such as Apple Inc (Lee, 2021^[19]).

As the fuel that powers our economies, the financial system can have a decisive role in driving investment towards projects that contribute to water security, or conversely in directing investment towards activities that exacerbate water-related risks. At the same, the financial system has much to lose through exposure to risk in its various forms and would have a vested interest in assessing and managing water-related risk and understanding the impacts and dependencies of financial beneficiaries on water resources. Yet, from a review of current practices, it appears that exposure to water-related risks may not be fully understood nor managed by the financial sector. This Working Paper therefore aims to support dialogue between the water community and the financial community, by exploring recent developments that shape how the financial sector understands the concept of the financial materiality of water-related risks.

1 Understanding financial materiality

1.1. Why are we talking about financial materiality and impact materiality?

Bolstered by Paris Agreement commitments adopted at United Nations (UN) Climate Change Conference of the Parties (COP 21), the financial sector has become an important arena for climate action. It is now subject to both growing interest and pressure to align investment activity with climate goals and manage climate-related risks. The financial sector equally has an important role in protecting the environment from the negative impacts of economic activities. There is growing interest in nature finance and understanding nature-related financial risks, which are risks to the financial system driven by nature loss. This is accompanied by increasing research on the global economy's significant dependence on nature, which was hitherto little understood (World Economic Forum, 2020^[20]), as well as greater acknowledgement of nature's role in resilience to climate change impacts (IPCC, 2023^[21]).

This implies that nature-related risks require consideration both together and independently from climate discussions. This message has been strengthened since the 15th Conference of the Parties to the Convention on Biological Diversity (COP15), where 196 countries adopted the Kunming-Montreal Global Biodiversity Framework, to halt and reverse biodiversity loss by 2030. Water-related risks, which is the focus of this paper, can be driven by both climate change and economic activities including land use change, overexploitation of natural resources or pollution, falling under both climate and nature-related risk categories.

Growing interest in environmental issues amongst investors, notably in the context of Environmental, Social and Governance (ESG) factors, has given rise to the concept of the 'financial materiality' of environmental challenges. ESG factors are a set of non-financial metrics that are used to evaluate the sustainability and societal impact of a company or investment. Originally an accounting principle, financial materiality prescribes that when an event's impact would affect the judgement of an investor it should be reported in financial statements. This also includes risks that might materialise in the future and affect the financial performance of the reporting (non-financial or financial) entity. This information is of interest to the reporting entity itself, as well investors and other actors such as credit rating agencies.

Yet, the financial materiality of climate and nature-related risks is subjective, in that it is a matter of judgement and assessment depending on specific circumstances of the organisation, its activities and its location, rather than clear-cut rules involving pre-established quantitative thresholds. Generally speaking, financial materiality is the threshold at which the inclusion or exclusion of financial information in financial statements would alter the overall understanding or opinion of those statements (IFAC, 2015^[22]).

These so called financially-material risks could, for example, take the form of increasing risk of drought or water pollution that would adversely impact the operation of assets within a firm's value chain, potentially leading to financial loss and stranded assets. Companies with water-intensive production such as agroindustry or mining are notably exposed, but water-related risks can also have an indirect impact across sectors, for example through a decrease in energy generation in countries where hydro, coal or nuclear power are widely used. This can lead to direct loss in revenue through disruption of operations, or increased expenditures on operations, maintenance or capital. Examples of direct costs could include new or increased costs for water procurement, or higher prices for energy or other water dependent goods. The

company might also need to invest in new technology with increased water-efficiency. Equally, indirect costs could take the form of administrative and compliance expenditures to align with new policies, or address water-related fines or litigation. This can also lead to increasing finance or investment costs, due to rising investment risk, the need for insurance or reduced capital availability (WWF, 2019^[23]).

The term “impact materiality” is also growing in importance and refers to the material impact that a reporting entity can have on nature, as well as on the economy and people. This recognises that while environmental challenges are driven by climate change, they are also heavily driven by economic activities. This information is therefore more broadly of interest to multiple stakeholders beyond the reporting entity and its investors, including employees, customers, suppliers and local communities. For example, impact reporting can provide information on how an entity contributes to water stress through groundwater depletion, metal contamination, plastic pollution, and water diversion amongst other harmful practices (CERES, 2022^[24]).

1.2. Financial materiality and environmental impact are together an emerging driver of financial decision making

In the context of EU legislation, financial materiality and impact materiality together are referred to under the umbrella of ‘double materiality’ (GRI, 2022^[25]). The term double materiality encompasses both financial and impact materiality together and suggests that companies should not only focus on how ESG issues impact on the company, but also consider how the company impacts on ESG issues. Taking the example of water, assessments of impact and financial materiality would both aim to determine which water-related risks are significant to a company. But the information assessed for impact materiality or financial materiality would meet different aims and target audiences. Reporting on financial materiality is of relevance to stakeholders who have a financial interest in a company’s performance, and therefore are assessing the impact of water-related risks on profit or value. Impact materiality targets a broader group of stakeholders, such as civil society and local communities, which implies that businesses should contribute to water security, or at least preserve resources that it comes into contact with, for the benefit of all its stakeholders.

The concept of double materiality has been at the heart of the debate between major reporting standards, as it raises the question of whether businesses should be responsible for issues beyond those that have a clear or direct financial impact on the business. This concept also highlights the interconnectivity of the two types of materiality, where impact materiality can lead to increased exposure to financially material risks. The broader concept of double materiality can arguably have greater transformational potential, as it considers longer-term implications in terms of both financial performance and sustainable development (Adams et al., 2021^[26]).

The financial system has numerous channels through which it can mitigate water-related risks. For example, at portfolio level, risk management strategies can include diversification or hedging. In the context of ESG investing strategies, ESG factors, which can include water within the environmental pillar, can be used to screen investments or tilt portfolios, which means to overweigh the portfolio with investments that have a high ESG rating (OECD, 2020^[27]). At the level of the investment, financial risks related to water can be eliminated or mitigated by transferring the risk to a third party via insurance or financial de-risking instruments. Shareholder engagement can also be used to encourage the firm to take actions to reduce the likelihood or severity of the risk or set aside financial resources to cover potential future losses. While often considered the option of last resort, risks can also be eliminated by cutting off finance flows to certain sectors or regions through divestment (OECD, 2021^[6]).

Identifying material risks can be a strong motivator for taking action to mitigate the potential financial impact of the risk. When risks, such as water-related risks, are considered financially material, action to minimise their financial impact generally ensue (ECB, 2020^[28]). Identifying risks, dependencies and impacts, can

also highlight opportunities to invest in new water-related markets, in water efficiency, in new products and services, or in ensuring supply chains are resilient against water impacts (CDP, 2023^[29]).

The water community has been advocating for more financing for investments that contribute to water security and sustainable growth, including through climate adaptation and resilience. While the consequences of water-related risks becoming financially material for the financial system could be various, this can help trigger action by financial actors to contribute to the mitigation of these risks. Notably, the identification of risks can lead to engagement with companies to influence corporate behaviour to mitigate the impacts of risks. Strikingly, a recent study by CDP identified that the cost of water-related risks to businesses could be as much as USD 301 billion. But taking action to address water-related risks, would be less than one fifth of this cost, estimated at USD 55 billion, (CDP, 2021^[30]).

1.3. Transmission channels for water-related risks to the financial system

Climate and nature-related risks can be transmitted to the financial system through impacts on corporates, households, sovereigns, and financial institutions. Relevant financial institutions could be loosely categorised under banks, the insurance and reinsurance ((re)insurance) companies, asset owners (such as institutional investors and sovereign wealth funds), asset managers, and central banks (OECD, 2021^[6]).

For example, banking activities can be exposed to credit default if borrowers are unable to repay loans due to a water-related event or a change in policy that impacts on their business model. For insurers, an inaccurate assessment of the risks with an insurance policy, due to an unforeseen water-related event, could lead insurer's costs to significantly exceed earned premiums. Asset owners can be exposed to water-related risks through corporate securities, particularly in infrastructure, agribusinesses and industries highly dependent on water availability or quality. Central banks have become the largest asset owners of advanced economies since the Great Financial Crisis in 2008; therefore, they are exposed to the same risks as other asset owners. Asset managers are also exposed to the consequences of higher perceived or real risks in their portfolios by their clients. When water-related risks materialise, clients may ask to sell off related assets, which may lead to a decrease in valuation and financial performance (OECD, 2021^[6]).

Risk drivers can take various forms. The European Central Bank categorises climate and environment-related risks under physical and transition risks, which are respectively risks linked to physical hazard, and the business-related risks that ensue from societal and economic shifts towards climate and environmental goals (Table 1.1). For example, water-related risks can affect an entity through the destruction of physical capital, disruption of production and supply chains, adaptation costs, and deterioration of macroeconomic conditions. With respect to transition risks, an entity can also be impacted by changes in public policies, legislation and regulation, changes in technology and changes in market and customer sentiment (ECB, 2020^[28]) (ECB, 2021^[31]).

Table 1.1. ECB examples of climate and nature-related risk drivers

Physical risk		Transition risk	
Climate-related	Environment-related	Climate-related	Environment-related
Extreme weather events	Water stress	Policy and regulation	Policy and regulation
Chronic weather patterns	Resource scarcity	Technology	Technology
	Biodiversity loss	Market sentiment	Market sentiment
	Pollution		
	Other		

Source: adapted from (ECB, 2021^[31])

A further risk category which is gaining more prominence is liability risk, which notably takes the form of litigation by environmental groups. The legal challenges to Tesla in 2021 are an illustrative example, which had the potential to delay or even stop Tesla's USD 5.7 billion Brandenburg manufacturing project, with implications for the project's investors and lenders. The Nabu and Gruene Liga groups sued Brandenburg's environment office, citing a failure to take into account the impact of climate change when approving a 30-year permit to pump more groundwater for Tesla's factory (Bloomberg, 2022^[32]).

Water-related risks can be driven by climate change or economic activities including land use change, overexploitation of nature resources or pollution, falling under both climate and nature-related risk categories. These risks can then transmit to the financial system through various channels. Figure 1.1 provides an illustration of how physical, transition and liability risks can have various economic impact on business operations, such as, disruption of activities and value chains, or price volatility of raw materials. These impacts then are transmitted to the financial system in the form of credit, market, liquidity, business and underwriting risks (Table 1.2).

Figure 1.1. Transmission channels for water-related risks to financial actors

Type of risk	Water-related risk	Economic impact	Financial risk
Physical risks Climate Change Land use change Overexploitation of natural resources Pollution	Flooding Water scarcity Polluted water Disruption to freshwater system	Disruption of activities Disruption of value chain Raw material price - volatility Adjustment or relocation of activities Capital destruction	Credit Market Liquidity Business Underwriting risk
Transition risks	Policy and regulation Technology Business model innovation Consumer or investor sentiment		
Liability risks	Litigation		

Source: adapted from CISL (2021) Handbook for nature-related financial risks; NGFS (2020) Overview of Environmental Risk Analysis by Financial Institutions; van Toor, Joris; van Oorschot, Mark et al. (2020) Indebted to nature: Exploring biodiversity risk for the Dutch financial sector

Table 1.2. Financial risks

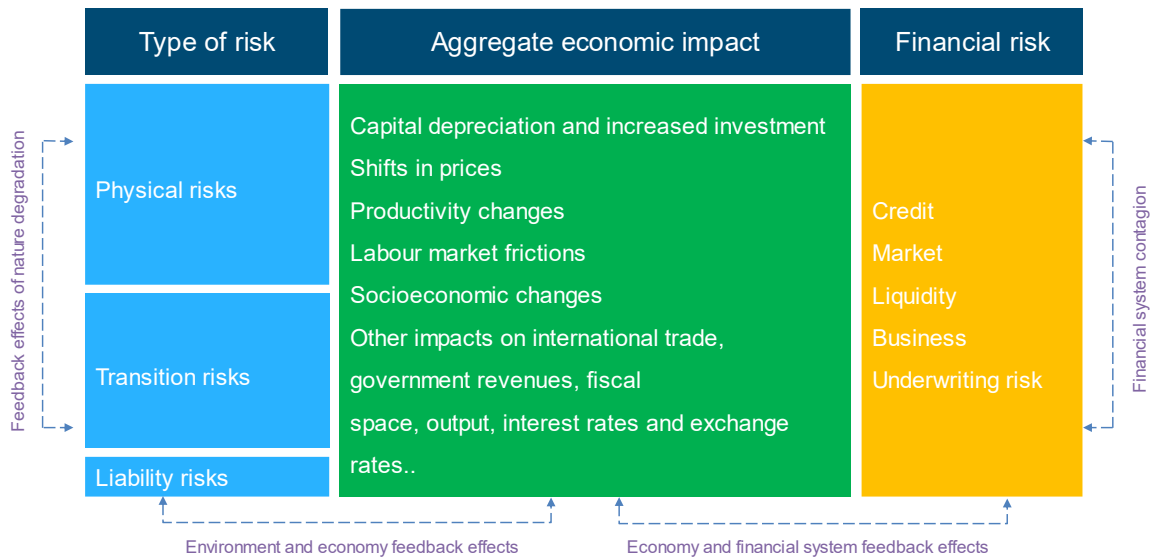
Type of risk	
Credit risk	Risk that a borrower will not pay an amount owed.
Market risk	Movements in stock prices, interest rates, exchange rates, and commodity prices.
Operational risk	Risk that affects operations of an organisation, either from risks within the operations of an organisation or from external events outside of the control of the organisation.
Business risk	Risk associated with operating earnings and reflected both sales risk and operating risk.
Underwriting risk	Underwriting risk is the loss borne by insurers and reinsurers.

Source: Authors.

Climate change and environment-related risks, including water-related risks, can also lead to structural changes that affect economic activity at macro-level, with important implications for the financial system.

This includes for example, capital depreciation and increased investment in affected zones, shifts in prices and productivity changes. Figure 1.2 illustrates how these risks have the potential to create adverse macroeconomic shocks, with externalities that propagate in the form of macro-financial feedback loops, which could impair financial stability.

Figure 1.2. Macro-economic transmission channels



Source: adapted from CISL (2021) Handbook for nature-related financial risks; NGFS (2020) Overview of Environmental Risk Analysis by Financial Institutions; van Toor, Joris; van Oorschot, Mark et al. (2020) Indebted to nature: Exploring biodiversity risk for the Dutch financial sector

At the same time, transmission channels can flow in both directions and the materialisation of risks can be exacerbated through feedback loops between nature and economy or the economy and financial system (CISL, 2021^[33]). For example, exposure to water-related risks can impact on the credit rating of a sector. However, a higher interest rates will create a costlier borrowing environment and deter investments in new capex or efficient technologies that could improve water-use. This in turn can increase the likelihood that more water is consumed in the sector.

It is also important to note the interplay between different nature and climate risks. For example, deforestation and land cover changes (such as paving surfaces with impermeable materials) can have implications for water-related ecosystem services. What were previously tolerable levels of water (or rainfall) can aggravate flooding or trigger landslides, as water can no longer penetrate soils or as the surface area has lost water retention capacity. Similarly, loss of soil moisture in peatlands can lead to a release of stored greenhouse gas emissions (IUCN, 2021^[34]).

1.4. Determining materiality

Determining financial materiality, as noted earlier, is a matter of judgment, in that it requires assessing the specificities of an institution's business model, operating environment, and risk profile is crucial when considering the potential impacts of climate change and environmental degradation. These factors can greatly influence an institution's vulnerability to both physical and transition risks. Regardless of an institution's size, its concentration in a market, sector, or geographic area can increase or decrease its exposure to physical and transition risks. A higher concentration can make the institution highly vulnerable to the impacts of climate-related change and environmental degradation (ECB, 2020^[35]).

For example, physical risks will depend on the location of specific assets, the risk they are exposed to in each location, and vulnerability to said risks, and risk mitigation measures in place, including insurance coverage. Data is therefore a critical first step to assessing a financial system's exposures to physical risk drivers. This requires granular information on the geospatial characteristics of financial institutions' exposures, combined with data on physical risk drivers (ECB, 2021^[31]). For transition risks, financial system actors need to assess multiple industries and consider how their situations will evolve under a transition to a zero-carbon and more environmentally sustainable economy. National policies and international commitments can create an additional layer of complexity, where firms must base their assessments on uncertain or inconsistent mid to long term policy.

The financial materiality of a risk will depend on the likelihood of the risk materialising and generating financial impacts at some point in the future. Insurance can mitigate the impacts of risks by transferring the risk to a third party. This means that financial materiality assessments will only look at the residual financial impact remaining for the assessing entity. Materiality also depends on the relative impact on the bearing entity of a given risk, given the financial resources it has at the time of impact to cover for it. For instance, the loss of a house to a flood may be financially material to a household if the house was a large part of their net worth and the damages are not covered by insurance. But the same loss of the same house may not be financially material for the bank that owns the mortgage, as this represents a small loss in terms of the bank's resources, and the risk was insured or hedged (OECD, 2021^[6]).

In addition, the evaluation of financial materiality is dependent on the present value attributed to a risk that materialises in the future. For any discount rate above 0, the further in the future these costs will occur, the lower their net present value will be. Changes in discount rates will modify the materiality of future risks assessed at the present time, even when the evaluation of the future impact is unchanged. For example, this may mean that the net present value of the cost of relocating operations in seven to ten years due to increasing water stress in region, could be negligible today if a high discount rate is used. This would therefore lead the business to disregard the risk in decision making.

However, this approach to assessing materiality can lead to important underestimations of risks to the reporting company, its investors, and the financial system as whole. In light of rapid and unprecedented climate change, assessing the financial materiality of water-related risks is not a static exercise but a dynamic one. Estimations of risks based on past patterns will likely underestimate future risks. Impacts of water-related events that do not meet the financial materiality threshold today could very well do so in the future if they increase in frequency and intensity (SASB, 2020^[36]). In addition, a firm's own negative impact on nature, for example, localised water pollution or depletion, can increase the firm's own exposure to risks, highlighting the interconnectivity of impact and financial materiality. Water risks are closely interlinked with risks to ecosystems and biodiversity and can lead to cascading effects and increased impacts.

It is important to also consider the macro-economic implications of water-related events, such as repeated widescale flooding or prolonged drought. These have the potential to create adverse macroeconomic shocks that impact on the operations or decision making of financial or non-financial institutions, with externalities that propagate in the form of macro-financial feedback loops (NGFS, 2022^[37]). This points again to the importance of dynamic assessments of financial materiality, which assess the real economy and financial sector feedback loops in response to shocks.

The discussion on determining financial materiality underscores that water-related risks are only financial material if the assessment of their relative impacts on the company determines them to be so. However, the negative impact of the company's decision making on water resources will not be considered in these assessments, unless they directly contribute to financially material risks to the company. Only when impact materiality is also considered, would impacts on water-resources be considered irrespective of the company's own exposure to risk. This illustrates how reporting on double materiality would significantly expand the reporting company's responsibilities, and has therefore been a key source of debate, and has not yet been introduced into reporting regulation.

2 Financial markets are not fully aware of their exposure to water-related risks at present

2.1. Water-related risks are material in the economy

Water is at the heart of both the climate change and the nature crises. Climate change is an increasing pressure on water systems and 90% of all natural disasters are water related (UNEP, 2023^[11]). At the same time, water-related risks are embedded within other key environmental challenges, including biodiversity loss, and socio-economic challenges, such as poverty, food security, green energy transition, and domestic and international conflicts. By 2050, the number of people exposed to floods is expected to grow from the current 1.2 billion to 1.6 billion (UN, 2020^[41]) and 52% of the world's population is projected to live in water-stressed regions (Colin et al., 2018^[5]).

Many parts of the world face concern over deteriorating water security. For example, more than 80% of India's population lives in districts that are highly vulnerable to extreme hydro-meteorological disasters. Over the past decades, weather events in India have become more extreme, with storms intensifying into cyclones, droughts affecting more than half of the country, and floods of unprecedented scale (Mohanty and Wadhawan, 2021^[38]). In another example, Pakistan in just a few decades has transitioned from abundant water supply to a water-stressed country; now 'over 80% of the total population in the country faces severe water scarcity for at least one month of the year' (PIDE, 2022^[39]). Brazil, known for its abundant water resources and home to the Amazon river faced in 2021 its worst droughts in over a century, impacting hydroelectric dams and reservoirs, notably along the Parana river basin, as well as the production of crops such as coffee, corn, sugarcane and oranges (NASA, 2021^[40]).

This is not exclusive to emerging economies. Water stress has been characterised as the largest medium-term climate risk for Europe's biggest economies. Greece, Italy, Spain and Belgium stand out as the most exposed. This is of concern for heavy water users, such as agriculture, manufacturing, and energy, as well as other activities, such as the data centres of technology and telecom companies, which require high volumes of water for cooling purposes (Mytton, 2021^[41]). Water stress is also causing disruption to supply chains. For example, in recent years, cargo barges on the Rhine River in Germany have faced loading and transportation issues because of critically low water levels (Naik, 2021^[42]).

The impact of water-related events comes with a high increase in damages across the economy. In the United States alone, since 1980, there have been 338 weather and climate disasters where overall damages were greater than USD 1 billion, and which combined exceed USD 2.295 trillion (NCEI, 2022^[43]). Flooding alone accounts for some 40% of all loss-related natural catastrophes since 1980, totalling more than USD 1 trillion (MunichRe, 2020^[44]).

The regularity of these occurrence is increasing. Over a quarter of these 338 large weather and climate disasters took place after 2016, with the rate of events increasing from 3 per year in the 1980s to nearly

18 per year in most recent years (NCEI, 2022^[43]). In 2021 alone, flooding accounted for USD 82 billion in losses, nearly a third of all economic losses from natural catastrophes in that year (SwissRE, 2022^[45]). The July 2021 flooding in Central Europe was the costliest natural catastrophe in modern European history and the costliest flood event globally to date, with estimated overall losses of USD 54 billion (MunichRe, 2020^[44]). In 2022, the costs of recorded drought and flood events already amounted to USD 10.2 billion between January and September (NCEI, 2022^[43]).

Businesses, households and governments bear the brunt of these risks, when risk mitigation measures are not put in place. As an illustration, of the USD 82 billion in losses from flooding in 2021, only USD 20 billion was insured, indicating that over three quarters of these losses were material to different economic actors. It is estimated that sovereign climate risks, including water-related risks, amount to about USD 78 trillion, equivalent to about 57% of the world's current GDP Power Purchase Parity (PPP), which is situated along flood-prone coastlines, riverways, and low-lying deltas (427, 2020^[46]).

Companies in key industries are already losing billions because of the global water crisis. The 2020 CDP survey on water security found that the financial value of detrimental water-related business impacts on over 2 900 corporates amounted to USD 16.7 billion. Currently identified water-related risks could have impacts on the business value of up to USD 336.3 billion in the future (CDP, 2021^[30]). In fact, water risk factors are already stranding assets. Throughout the coal, electric utilities, metals and mining, and oil and gas sectors, they found that USD 13.5 billion in assets are already stranded and a further USD 2 billion is at risk due to water issues (CDP, 2022^[13]). While large firms are often able to absorb the financial implications of asset-stranding water events, this is much more challenging for smaller companies that make up most of the market in these sectors and the financial institutions investing in them.

2.2. The banking sector does not yet fully grasp its exposure to water-related risks

The banking sector is exposed to water-related risk through numerous channels. A large part of bank lending in advanced economies is for mortgages that can be affected by water-related events, if they impact the market value of properties or the solvency of borrowers. Financial derivative products are another substantial part of banks' books, which are held by banks to hedge the risk of their clients or as trading instruments for banks. These could be impacted by the materialisation of water-related risks that impact on wide range of prices, such as for water itself, agricultural or industrial commodities dependent on water availability, such as irrigated crops, livestock, steel, mining, blue chip, and hydropower, among others. Credit default swaps, which are insurance provided by banks against the default of a corporate or sovereign issuer, could also be affected by water-related losses to corporates and sovereign issuers, if credit quality is affected by water-related risks (OECD, 2021^[6]).

Yet, emerging evidence from central banks and financial institutions indicates that water-related risks are not being fully captured in current approaches to assessing risk. In 2021, a study by the ECB together with the European Systemic Risk Board (ESRB), found that physical risks did not appear to be priced in the Eurozone banking system. The study considered corporate exposures to several climate-related risks, including river and coast floods and droughts. It found only modest pricing of the financial sector's exposure to these risks, which likely represents only the lower bound for climate-related losses in the financial system. For instance, of bank credit exposures to non-financial corporations in the Eurozone, only 10.6% were subject to high or increasing flood risk, 1.4% to coastal floods/sea level rise, and 12.2% to water stress. Out of the banks surveyed, only two-fifths had performed a mapping of climate and environment risk exposures (ECB, 2021^[47]).

In 2022, a follow-on review of 186 banks with total combined assets of USD 25 trillion led to a broad acknowledgement within the banking sector of the materiality of physical and transition risks within the current business planning horizon. The review found that more than 80% of institutions perceive that risks

from climate change and environmental degradation would have a material impact on their risk profile and strategy, with 70% seeing material risk within their business planning horizon of three to five years (ECB, 2022^[48]). Since the 2021 review, over 85% of survey institutions had performed an initial mapping of their risk exposures, allocated responsibilities within the organisation, set initial key performance and risk indicators, and developed a qualitative mitigation strategy for at least part of their risk exposures. However, approaches taken vary across institutions and the ECB highlighted a need for more methodological sophistication and use of more granular data on risk profiles. In addition, while credit risk receives the most focus, less analysis is being undertaken on market and operational risks (ECB, 2022^[48]).

At the individual bank level, HSBC performed a stress scenario to assess the potential impact on the credit risk of water stress in heavy industry companies in an East Asian country. This test highlighted how water-related risks could have a significant impact on the credit risk of HSBC bank's lending book (see Box 2.1) (CISL and HSBC, 2022^[49]).

Box 2.1. Use case on the impact of water curtailment on credit rating of heavy industry companies in East Asia

HSBC, one of the world's largest banking and financial services organisations, led an internal risk assessment process in close collaboration with the University of Cambridge Institute for Sustainability Leadership (CISL) team, who provided guidance on nature-related risks. The purpose of this use case was to trigger and support further assessments of nature-related risk across the financial system.

To better understand the nature-related financial risk posed by water insecurity, the use case applied a stress scenario to financials of heavy industry companies in an East Asian country with areas of very high-water stress, comparable to water stress in Cape Town.

The East Asian region was chosen due to availability of portfolio data in HSBC and presence of countries with areas of very high-water stress. The selection of the heavy industry sector was based on an initial assessment of the loan book's materiality, taking into account dependencies on water-related ecosystem services.

In the stress scenario, water services were disrupted for three months by non-climate drivers such as increasing exploitation of water or upstream land use change, which are amplified during periods of extreme weather variability. The objective of this study was to evaluate the potential influence on credit risk when disruptions occur in natural services due to non-climate factors like intensified water exploitation or changes in upstream land use. These disruptions are particularly amplified during periods of extreme weather variability, such as drought.

The credit risk consequences were:

- significant deterioration of the average portfolio credit risk rating
- more than a third of the companies analysed moving from Investment Grade to Speculative

The results from this initial exploratory assessment underscore the need for:

- further assessment of nature-related financial risks, such as water insecurity, given the financial materiality demonstrated by the use case
- the inclusion of water-related risks in financial institutions' risk frameworks
- better data and risk identification tools to enable these assessments to be conducted more easily.

The study found that risks are not currently considered in banks' credit risk management methodologies, which creates a potential risk to banks' financial stability. This study pointed towards a need for an industry-wide framework and relevant tools to assess nature-related financial risks and embed them into banks' risk management practices.

Source: (CISL and HSBC, 2022^[49]) Nature-related financial risk: use case.

2.3. There is growing awareness in the insurance sector of the importance of water related risks

Where insurance is provided via the private market, as underwriters of natural catastrophe risks, the (re)insurance sector is at the frontline of climate change and environmental degradation. The long maturities of (re)insurance company portfolios, which span over several decades in advanced economies, will be exposed to increasing water-related risks over a longer period.

For instance, floods have been highlighted as a cause of regular and sometimes devastating damage. In 2021 alone, flooding accounted for USD 82 billion in losses, nearly a third of all economic losses from natural catastrophes in that year. Of the USD 82 billion, only USD 20 billion were insured (SwissRE, 2022^[45]). The July 2021 flooding in Central Europe was the costliest natural catastrophe in modern European history and the costliest flood event globally to date, with estimated overall losses of USD 54 billion (MunichRe, 2020^[44]).

Insurers distinguish between "primary" and "secondary" perils, where "primary perils" refers to large-scale catastrophes, notably tropical cyclones, earthquakes and European winter storms. The term "secondary perils" is an umbrella term for natural catastrophes that typically generate losses of low to medium magnitudes, such as thunderstorms, hail and tornadoes, drought, wildfire, snow, flash floods and landslides. A reinsurer, Swiss Re, noted that insured losses have been elevated over the last five years due to recurring high-loss secondary peril, with multi-billion insured loss outcomes. This trend is new, and in 2021 there were notably two separate secondary peril events that caused losses in excess of USD 10 billion each: the winter storm Uri in the US and devastating floods in central-western Europe. Typically, secondary peril events have been less well monitored and modelled, which is problematic given the rise of their associated losses. This points to an important need for secondary perils to be better understood for the purpose of a more complete and accurate risk assessment (SwissRE, 2021^[50]; SwissRE, 2022^[45]).

In Europe, a common practice from insurers is to not include climate change-related risks in their pricing methodology for non-life insurance contracts, as most contracts will have a short duration, which allows them to reprice annually. In practice, actuarial analysis is only one input to pricing decisions, and reinsurers' pricing is also influenced by the appetite of global capital providers and reinsurance pricing cycles associated with the occurrence of extreme events (EIOPA, 2021^[51]). However, past events have already shown that it will not always be possible to adjust premiums gradually over time, with large, unexpected events occurring with unexpected frequency. For example, Berenberg insurance estimated that European floods in 2021 will cost the German reinsurance industry between USD 2 billion and USD 3 billion. The scale of the floods and how close on the heels they came to other floods were both unexpected by Berenberg insurance (Naik, 2021^[52]). At the same time, simply pricing water-related risks with increased premiums could adversely affect insurance coverage and lead to an increase in the protection gap over time.

With high levels of uncertainty and potentially large impacts, water risks are a major emerging risk for the (re)insurance industry and for global society, which should spur insurers to explore a new set of solutions. The growing frequency and severity of floods is giving rise to new measures and partnerships. The UK has developed Flood Re, a joint initiative between the government and insurers. Its aim is to increase the affordability of flood cover as part of household insurance policies. The insurer can choose to pass the flood risk element of their insurance policies to Flood RE for a fixed price and be reimbursed on flood related claims from policyholders. This helps keep premiums down for the end customer (RE, 2023^[53]).

Similarly, in the US, Community-Based Catastrophe Insurance (CBCI) is arranged by local government organisations to provide affordable coverage for families and businesses. The scheme creates incentives for risk reductions with premium discounts for household or community-scale mitigation efforts (III, 2022^[54]). In addition, there are increasing examples of parametric coverage, where compensation is triggered when certain conditions are met (for example a given wind speed or earthquake magnitude), rather than through specific claims for damages. In the UK, parametric coverage is being applied to flooding, with sensors installed at properties. When the sensors are triggered, the claims process begins without the need for inspections or further documentation (III, 2022^[54]). Parametric policies can significantly reduce the transaction costs for insurance. These approaches have been most common with commercial clients, but pilots are now expanding these schemes to residential buildings and micro-enterprises in emerging economies (III, 2022^[54]).

In order to address the risk assessment challenge, new data sources on risk information, improved risk modelling and analytical tools have a vital role to play in improving and streamlining underwriting, pricing, policy administration, and claims processing. This will also require deployment of advanced technology to develop risk-prevention solutions and access accurate, granular and real-time data (III, 2022^[54]).

However, it is becoming clearer that risk transfer alone through insurance will not be sufficient to address the challenge ahead. Given the (re)insurance industry's expertise in assessing and quantifying risks and understanding loss trends, it can play an important role in promoting resilience, through long-term planning, new technologies to reduce water consumption and preventive measures to avoid flooding, which can minimise the overall financial burden. This can be done by educating policyholders about risk mitigation and embedding incentives to implement resilience measures in their pricing policies (III, 2022^[54]).

2.4. Pricing of water-related risks in the financial system is varied

Financial market participants appear to be starting to look at climate change as a potential source of financial vulnerability, but evidence on how this impacts decision in the financial system is still unclear. For example, only a very small proportion of global stocks are held by sustainable funds, which consider climate risks and typically have a long-term view. Despite rapid growth in recent years, sustainable funds still account for only about 4% of the global fund market (UNCTAD, 2022^[55]).

Under the risk of stranded assets, one could assume that investors would demand a premium for holding assets exposed to physical risks, such as water-related risks, which will increase over time under climate scenarios. Following this logic, these assets would have a lower price compared with assets with similar characteristics that are not exposed to increasing physical risk. The IMF's 2020 Global Financial Stability report studied aggregate stock market data for 68 economies to assess whether markets were pricing climate risk. The report found that physical risks from climate change do not appear to be reflected in global equity valuations. This works suggests that there is no clear evidence that investors are paying attention to climate change risks, and there is a need for greater stress testing and climate risk disclosure to better assess physical risk (IMF, 2020^[56]). However, this research also provided an illustration of how the materiality of water-related risks is highly contextual. The impact of large climatic disasters on equity prices had been relatively modest where there rates of insurance penetration were higher and where there was greater sovereign financial strength, both of which mitigate the impact of large disasters on equity returns (IMF, 2020^[56]).

There is mixed evidence for the pricing of climate change physical risk in other asset classes. In the United States, counties projected to be adversely affected by rising sea levels faced higher costs for underwriting fees and initial yields when issuing long-term municipal bonds, in comparison with other long-term municipal bonds from counties unlikely to be affected by climate change and short-term municipal bonds. This implies that the market does in some cases price climate change risks for long-term securities (Painter, 2020^[57]).

However, in another example, BlackRock observed two municipal bonds with similar characteristics: the first, Jupiter, Florida, USA, is exposed to climate risks through its location and its numerous waterways, which make the city especially vulnerable to tropical storms and hurricanes; and the second, Neptune, New Jersey is relatively insulated against severe storms. The comparison of a Jupiter water revenue bond against a Neptune bond with similar characteristics found identical yields after adjusting for credit quality. Similar results were found on other spot checks of bonds in areas of relatively high and low climate and water-related risk (BlackRock, 2019, p. 11^[58]).

2.5. Water-related risks are financially material at macro-level, with implications for financial stability

It is important to note that a large share of losses linked to extreme weather and climate-related events are not insured. In the European Union, in 2019 only 35% of the total losses caused by extreme weather and climate-related events were insured, leaving an insurance protection gap of 65% (EIOPA, 2021^[51]). Globally, estimates of the flood protection gap are even larger. ‘Insurance has covered just 7% of the aggregate economic losses from flood events in emerging markets in the last 20 years, and 31% in advanced economies’ (III, 2022^[54]). Flooding accounts for some 40% of all loss-related natural catastrophes since 1980, with losses worldwide totalling more than USD 1 trillion (MunichRe, 2020^[44]). In certain jurisdictions, the exposure of insurance companies to certain water-related risk is shared by the State (such as France with the “catastrophes naturelles” legislation). Alternatively, some State agencies may offer coverage where private insurance is not available (such as the Federal Emergency Management Agency in the US) (OECD, 2021^[6]).

Therefore, the lion’s share of total losses from water-related events is borne by property owners, businesses and governments. The macro-economic impacts of these risks can therefore be widescale, leading to socio-economic changes and impacts on international trade, government revenues, fiscal space, output, interest rates and exchange rates (Figure 1.2). This can impact on the solvency of sovereign borrowers due to immediate investment needs following a water-related event, decreased tax revenues, and increased social spending.

In this context, major water-related events could potentially negatively affect sovereign bond markets. More research is needed on sovereign borrowers’ exposure to water-related risks, which has not been fully priced in by financial markets (ECB, 2021^[47]). As the physical impacts of climate change become more severe, the likelihood of physical risks, such as water scarcity and floods, increases. In the past, where major events have taken place, the (re)insurance sector has tended to react by significantly increasing premiums, adding policy exclusions or refusing to renew cover, which ultimately leaves the policyholder with no coverage or with difficulties paying for such coverage. This could lead to decreasing insurance coverage, and the protection gap may correspondingly increase over time, with further implications for sovereign risk (EIOPA, 2021^[51]).

Large water-related events could impact a country’s financial system through widescale losses on loans and investments, increased default risk and reduced access to funding. These risks can have knock-on effects as the behaviour of one institution in response to environmental risks can affect the behaviour of others. For example, environmental risks can disrupt infrastructure and supply chains that support the financial system, which can increase credit and liquidity risks for financial institutions that operate in affected regions. In a country example, a stress test by the Netherlands Central Bank (DNB) (seen in Box 2.2) provides an illustration of potential losses that banks could face due to a major flood event. Potential impacts of extremely severe flooding notably in the densely populated western regions of the Netherlands, would have sizeable capital impacts on Dutch banks, with the potential to affect financial stability in a material way (Coloia and Jansen, 2021^[7]).

This points to an important need, for policymakers and the financial sector alike, to understand how and when floods could become a systemic-risk concern. Risk quantification is an essential step to incorporating climate-change-related concerns into financial stability monitoring and to enabling financial firms to properly manage climate-related financial risks. It is also crucial for supervisors and regulators to be able to assess whether financial firms have taken adequate measures to control risks.

The stress test undertaken by DNB has implications for various policy areas, including macroprudential policy (Coloia and Jansen, 2021^[7]). Indeed, central banks are starting to become aware of the macro-financial risks of environmental degradation. Notably, the Network for Green the Financial Sector (NGFS), a network of 66 central banks, notes that “nature-related risks, including those associated with biodiversity

loss, could have significant macroeconomic implications, and that failure to account for, mitigate, and adapt to these implications is a source of risks for individual financial institutions as well as for financial stability“ (NGFS, 2022^[37]). This highlights the importance of financial institutions considering water-related risks and implementing strategies for managing and mitigating them, as these risks can have significant impacts on the financial system through their effects on individual financial actors and the economy as a whole.

Box 2.2. Evidence from a stress test for the Netherlands

This study was undertaken by the Central Bank of the Netherlands (DNB), to look at conditions under which floods become a financial stability concern. Climate change is leading to slow shifts in the weather patterns, which increase the probability of extreme weather events. Historical records already show that flooding can lead to economic damage. Rising flood incidence can especially affect low-lying countries, such as the Netherlands, both through property damage and macro-financial adversity.

The study used a stress test framework and geocoded data on real-estate exposures for Dutch banks, to understand when floods would start impairing financial stability. This was based on a combination of statistical models and expert judgment, taking into account a range of factors such as the location and elevation of bank branches and assets, the value of bank assets, and the potential impact of flood-related infrastructure damage.

The results of the stress test indicate that the banking sector is sufficiently capitalised to withstand floods in unprotected areas where there is relatively little real estate. However, capital depletions would increase quickly if more severe floods were to hit the densely populated western part of the Netherlands. The potential losses that banks could face in the event of a major flood event are significant, with estimated losses ranging from USD 10 billion to USD 25 billion depending on the severity of the flood. The impact of a major flood event on banks would depend on a range of factors, such as the effectiveness of flood defences, the ability of banks to continue operating during and after a flood, and the availability of insurance and government support.

DNB calculations suggest capital impacts of more than 700 basis points over a one-year horizon. Such a major financial impact of floods, together with additional adversity for non-banks, suggest that climate-change physical risks have a potential to affect financial stability in a material way.

These findings have possible implications for various policy areas, including macroprudential policy. A conclusion of this paper is that if climate change were to continue unabated, at some point, flood events could have implications for systemic risk. By taking a proactive approach to managing flood risk, banks and policymakers can help ensure that the financial system remains resilient and can continue to support the needs of individuals and businesses in the face of climate change.

Source: (Coloia and Jansen, 2021^[7]) Evidence from a stress test for the Netherlands

3 Financial market regulation and guidance, a baseline for assessing water-related risks

The 2008 financial crisis prompted governments to increase financial regulation, both at the international and national levels, and this takes different forms for different actors. It is important to consider how water-related risks are considered (or not) by the regulatory frameworks that govern the financial systems, as these provisions will establish the baseline for how financial system define and assess risks.

Laws and government agencies that oversee operations in the financial markets aim to ensure that markets function in an orderly, fair and transparent manner to protect investors, maintain market integrity and promote overall economic stability.

In particular, insurance providers and banks are governed by prudential regulation, which aim to ensure that the entities that it regulates can meet their financial commitments. Prudential regulations are the rules and regulations that “contribute to the safety and soundness of regulated entities and contribute to the stability of the market, with a view to protect policyholders” (OECD, 2020^[59]). This is typically done through standards including capital adequacy requirements, risk-based solvency, investment regulations and supervisory tools like stress testing and early warning systems.

Financial markets are also governed by regulations to protect investors and maintain the fair and orderly functioning of the securities market. In addition, reporting and disclosure standards for non-financial corporates determine the type of information that will be made available to the rest of the financial system.

3.1. Prudential regulation for the banking sector does not mandate reporting on climate and nature-related risks

Central banks play a critical role in the banking sector as supervisors and regulators assessing and providing guidance on micro and macro prudential risks. Across advanced economies, Basel III prudential regulation of banks, under the supervision of the Bank for International Settlements, aims at strengthening the solvency of individual banks to avoid a systemic banking crisis. Amended, after the Great Financial Crisis in 2008, Basel III provides a comprehensive set of measures to improve the banking sector's ability to absorb financial and economic shocks, improve risk management and governance, and strengthen banks' transparency and disclosures. This is complemented by regulation at the national level, but as banks are strongly connected between themselves via interbank lending, Basel prudential regulation aims to forestall the default of a given bank that may trigger the default of the entire banking system (BIS, 2021^[60]).

Amongst other updates, Basel III Pillar I notably increases minimum capital requirements for managing market risk. This requires banks to publish a solvency ratio, which compares the equity capital that the bank holds to the risks it bears. There are a number of risks that banks are required to report on under

prudential regulation. These include credit risks, which are risks on the lending activities of banks, market risks, on the trading activities of banks, and operational risks, stemming from the technical operations of a bank, such as cyber risk, fraud, litigation, and liability fines (Table 1.2.). Prudential regulation requires banks to maintain a prudential solvency ratio above 4.5% and if this requirement is not met, the regulator can take regulatory action against the bank, asking it to increase its equity capital, or restricting its licence to operate.

Table 3.1. Definition of risks in banks' prudential regulation

Type of risk	Definition
Credit risk	Internal assessment based on the probability of default and loss given default to account for guarantees or other recoverable amounts such as the value of mortgages.
Market risk	Computed on financial products that banks hold for trading purposes. The risk is evaluated on the basis of internal risk models based on the past observed probabilities of default (VAR calculation).
Operational risk	Technical risks such as fraud, cyber risk, and failure to operate following, for instance, fire, flooding or litigation.

Note: Value at Risk (VAR)

Source: Authors.

Other risks and capital buffers are included in prudential regulation under the Basel III framework's two other pillars. Pillar II focuses on supervisory review and requires banks to have a comprehensive assessment of their risk profile and management practices. Pillar III aims to enhance market discipline by requiring banks to disclose comprehensive and timely information on their risk profile, risk management practices, and capital adequacy (BIS, 2021^[60]).

It is important to note that prudential regulation under Pillar I of the Basel III framework does not currently mandate reporting on climate and nature risks, which would be an important means of ensuring the banking sector reported on water-related risks and acted in accordance with its exposure.

However, under Pillar II and III, there is potential to drive changes in banks' risk management practices and disclosure requirements in the coming years. Under Pillar II, banks are required to identify and assess all material risks, which would include environmental and climate risks, and to have appropriate risk management policies and procedures in place to manage these risks effectively. This includes assessing the physical risks associated with climate change, such as the risk of flooding or drought, as well as the transition risks associated with the shift to a low-carbon economy. Pillar III requires banks to disclose relevant information on their risk profile, risk management practices, and capital adequacy, including information on their exposure to environmental and climate risks. This increased transparency is designed to enhance market discipline by enabling investors and other stakeholders to make more informed decisions about the risks and opportunities. But this will require banks to develop appropriate strategies for managing and disclosing their exposure to environmental and climate risks (NGFS, 2021^[61]).

Central banks have started giving supervisory guidance on how to amend their risk models to account for climate and environmental risks (ECB, 2021^[62]) (Table 3.2.). Guidance is not yet mandatory and the uptake of this advice by banks in the Eurozone is still in the early stages. However, banks that systematically assess climate and environmental risks are already reporting on the material impacts of these risks, pointing to a clear gap in the sector's understanding of its exposure to risk (ECB, 2021^[62]).

Table 3.2. ECB examples of environmental risks drivers in prudential regulation

Risks affected	Physical risks (Of which water stress)	Transition risks (of which policy, regulation, technology and market sentiment)
Credit risk	The probabilities of default (PD) and loss given default (LGD.) of exposures within sectors or geographies vulnerable to physical risk may be impacted, for example, through lower collateral valuations in real estate portfolios as a result of increased flood risk.	Energy efficiency standards may trigger substantial adaptation costs and lower corporate profitability, which may lead to a higher PD as well as lower collateral values.
Market risk	Severe physical events may lead to shifts in market expectations and could result in sudden repricing, higher volatility and losses in asset values in some markets.	Transition risk drivers may generate an abrupt repricing of securities and derivatives, for example, for products associated with industries affected by asset stranding.
Operational risks	The bank's operations may be disrupted due to physical damage to its property, branches and data centres as a result of extreme weather events.	Changing consumer sentiment regarding climate issues can lead to reputation and liability risks for the bank as a result of scandals caused by the financing of environmentally controversial activities.
Other types of risks (liquidity, business model)	Liquidity risk may be affected in the event of clients withdrawing money from their accounts in order to finance damage repairs.	Transition risk drivers may affect the viability of some business lines and lead to strategic risk for specific business models if the necessary adaptation or diversification is not implemented. An abrupt repricing of securities, for instance, due to asset stranding, may reduce the value of banks' high-quality liquid assets, thereby affecting liquidity buffers.

Source: (ECB, 2021, p. 12_[62]).

Stress testing is a tool used by central banks to assess the financial system's resilience and ensure that banks have adequate capital and liquidity buffers to withstand adverse economic conditions. This tool is closely related to Pillar II of the Basel III framework. It provides a means for regulatory authorities to assess the resilience of individual banks and the financial system. In particular, stress testing involves subjecting banks to hypothetical scenarios that test their ability to withstand adverse economic conditions, such as a severe recession, a sharp increase in interest rates, or a sudden drop in asset prices. Regulatory authorities can use stress test results to identify potential weaknesses in the banking system and ensure that banks have adequate capital and liquidity buffers to absorb potential losses. In addition, stress testing promotes market discipline by providing investors with a better understanding of the risks faced by individual banks and the financial system. Application of climate and nature scenario analysis and stress testing can help to identify portfolio exposures, data gaps and inform the adequacy of risk management approaches. They can also help evaluate the banking sector's financial position under severe but plausible scenarios.

However, the evaluation of these risks comes with new data requirements, much of which is not readily available, as it concerns information on private households or businesses, which is often not in the public domain or only disclosed under differing reporting methodologies. Moreover, banks can no longer base their assessments on historic data, given the rapid changes in climate and regularity of water related events (Blijlevens and Wiersma, 2022_[63]).

As noted above, some central banks have already started to undertake stress testing. Notably, the Central Bank of the Netherlands (DNB) started to study flood risks in the country from a financial stability perspective. Initial results show that there are important implications for the financial systems, notably with respect to credit risks, with large mortgage exposure to flood risks. The experience of DNB highlighted that while comprehensive information on flood risk was available, there were notable gaps in the data needed to assess exposure and vulnerability to water-related risks and their financial impacts (see Box 2.2) (Coloia and Jansen, 2021_[7]).

Nevertheless, the ECB emphasises the “need for banks to take intermediate steps when data or methodological gaps exist. They should use qualitative metrics, develop proxies with the data sources that are available and adjust their strategies accordingly to enhance their resilience against climate and environmental risks. However, some of the supervisory expectations do not have considerable data needs, so banks should meet these expectations more quickly” (ECB, 2021^[47]).

3.2. Prudential regimes for (re) insurance undertakings are evolving to include sustainability risks

Private and public insurance approaches play a major role in estimating and mitigating water-related risks. Approaches to compensation and insurance within different national flood recovery systems varies across jurisdictions. In certain jurisdictions, the exposure of insurance companies to water-related risk is shared by the State (such as France with the “catastrophes naturelles” legislation). Other State agencies may offer coverage where private insurance is not available (such as the Federal Emergency Management Agency in the US) (OECD, 2021^[6]). In the Netherlands, no private flood insurance is available but ex-post compensation schemes are enshrined in legislation. Conversely, in other countries, such as Brazil, insurance may be provided solely via the private market, with no state compensation (Penning-Rowsell and Priest, 2015^[64]).

Climate and environmental risks are material for the insurance sector as they impact the insurability of policyholder property and assets as well as insurers' operations and investments. Water-related risks such as floods and droughts, are gaining increasing importance for insurers and the companies and individuals they insure. The financial implications of these risks can create prudential risks for insurers, by threatening their ability to meet their financial commitments. As a result, insurance regulators and supervisory authorities around the world are taking increasing notice.

The insurance sector is less internationally integrated than the banking sector, and insurance regulations will vary across countries and regions. For example, in the United States, prudential regulation is conducted by state-level insurance departments and the National Association of Insurance Commissioners (NAIC), which develops and implements common standards and best practices. In Australia, the Australian Prudential Regulation Authority (APRA) is responsible for the prudential regulation of the insurance industry. In the UK, it is conducted by the Prudential Regulation Authority (PRA), part of the Bank of England. In the EU, EIOPA coordinates the work of national regulators and provides guidelines for the sector. In other parts of the world, the responsibility for regulating the insurance industry may fall on central banks or financial supervisory authorities or ministries of finance or similar government departments.

While industry reports have highlighted the importance of water risks to the (re)insurance industry, there is currently no global approach by the insurance sector for water-related risks. Some countries or regions set specific actions or guidelines regarding water risks, such as standards for insurers to assess and manage water-related risks in their underwriting and investment activities. Other measures include stress tests and scenario analysis to evaluate the potential impact of water-related risks on insurers' financial stability. Regulators can also encourage insurers to develop and use catastrophe models that consider water-related risks.

For example, in Australia, APRA has issued guidance for insurers on how to identify, assess, and manage climate risks, which include water risks; and in the EU, the European Insurance and Occupational Pensions Authority (EIOPA) has also launched a discussion paper on the integration of climate change and environmental risks in the insurance sector to better address physical risk including river and coastal flood risks. (APRA, 2022^[65]) (EIOPA, 2022^[66]). It is worth noting that climate related water risks are still a relatively new area of focus for insurance regulators and supervisory authorities, and the specifics of how they are considered and addressed may differ depending on the country or region.

Solvency II, under the EU, provides an international set of standards for the assessment and management of risks, which can be applied to environmental risks such as water stress. Insurance companies are required to conduct their Own Risk and Solvency Assessment (ORSA) that considers the full range of risks to which they are exposed. In 2021, regulation was amended to require the integration of sustainability risks in the risk management and governance of (re)insurance undertakings. This means that sustainability risks need to be reflected in the investment and underwriting strategies of insurers. As part of the prudent person principle, insurers will also need to consider the potential long-term impact of their investment strategies and decisions on sustainability factors (EIOPA, 2022^[67]).

Further steps need to be taken towards integrating sustainability and climate factors into risk management frameworks, to identify and assess the potential impact of environmental risks on businesses and households. An opinion published by EIOPA in 2021 proposed to include climate scenario analysis in the ORSA to assess climate risks both in the short term and the long-term. Risk management frameworks could then be designed to address identified risk, for instance with measures to mitigate and manage water stress risks through reduced water consumption, increased water efficiency, or investment in water-saving technologies. This would also allow regulators to better understand how insurers address water risks and take action if they believe insurers are not take adequate measures (EIOPA, 2022^[67]).

The European Commission, as part of the review of the Solvency II Directive, has given EIOPA two additional mandates on sustainability risks. Under the first mandate, EIOPA should explore the potential for risk differentials related to assets or activities associated with environmental and social objectives. Given the expected increase in physical risk exposures due to climate change, EIOPA will also explore the potential for a dedicated prudential treatment of insurers' underwriting exposures related to climate change adaptation. The second proposed mandate requires EIOPA to regularly re-assess the appropriateness of parameters for natural catastrophe risk and, if necessary, provide an opinion on potential changes to the prudential framework (EIOPA, 2022^[67]).

3.3. Investment regulation takes a light-touch approach to managing climate and nature risks

There are numerous types of financial regulations, which aim to safeguard consumers against fraudulent activities and cultivate confidence in the financial industry. For example, financial market regulations can include securities laws, derivatives regulations, and pension regulations. In the US regulatory agencies include the Securities Exchange Commission (SEC) and the Commodity Future Trading Commission (CFTC). The Employee Benefits Security Administration of the US Department of Labour (DoL) is responsible for overseeing legislation governing private sector pension plans. In the EU, the European Securities and Markets Authority (ESMA) is responsible for securities and markets and the European Insurance and Occupational Pensions Authority oversees insurance and pension funds regulation.

The notion of financial materiality is part of investment regulations in the financial market. However, investor regulation focuses on ensuring the fair and transparent functioning of the market, rather than prescriptive investment guidance. While there are no specific regulations in place to address water-related risks, there is an increasing perception that climate and environmental risks fall under the broader mandate of protecting investors and promoting overall economic stability.

For example, the SEC requires public companies to disclose certain types of risks in their financial statements, which can be applied to environmental issues such as water scarcity. In 2022, the SEC proposed rules to enhance the disclosure of climate-related risks and metrics by companies in their registration statements and periodic reports. These would provide investors with greater insight into the potential material impact of climate risks on a registrant's business, results of operations, or financial condition. Companies would also be required to disclose the impact of climate-related events, such as severe weather conditions, on their financial statements (SEC, 2022^[68]).

In the UK, the government has announced new Sustainability Disclosure Requirements (SDR) whereby pension schemes and other asset owners would be required to disclose their sustainability-related risks, opportunities and impacts in a way that enables clear communication with savers.

Another example in the US demonstrates that there is resistance to new regulation that would negatively impact on ESG considerations. The US DoL issued a regulation under the Employee Retirement Income Security Act of 1974 (ERISA) that governs investments made by private pension and health schemes in the US. The rule on "Financial Factors in Selecting Plan Investments" included amendments to the "Investment Duties" regulation under ERISA, which would require pension plan fiduciaries to make investment decisions based solely on financial considerations and their impact on the returns of the investors. However, enforcement of this rule was suspended in 2021 while the DoL conducted further stakeholder outreach to determine how to incorporate ESG factors into investment evaluations, whilst also maintaining the fiduciary responsibilities of these plan's investment managers (DoL, 2021^[69]). The proposal was later updated by the DoL, and a final rule was issued in 2022 that will permit, although not require, retirement plan fiduciaries to consider the economic effects of climate change and other ESG factors more readily in investment decisions (DoL, 2022^[70]).

3.4. Corporate climate and nature-related disclosure is strengthening

Advances in disclosure are helping provide more information to investors on how companies are exposed to and manage ESG issues. In 2016 a key milestone for climate disclosure was the establishment of the Task Force on Climate-related Financial Disclosures (TCFD)¹ by the Financial Stability Board (FSB), which is an international body that monitors and makes recommendations about the global financial system to promote global financial stability. The next year TCFD published recommendations to the financial sector for more and better disclosures of financially material, or potentially material, climate-related risks. The objective of these recommendations was to promote more informed investment, credit, and insurance underwriting decisions and, in turn, enabling stakeholders to understand better the concentrations of carbon-related assets in the financial sector and the financial system's exposures to climate-related risks.

A number of disclosure initiatives exist. While the TCFD provides recommendations to the financial sector, the International Integrated Reporting² provides a structure for companies to report on their responses to the external environment in their communication about their strategy, governance, performance and prospects. This type of reporting can help investors assess the financial materiality of water risks, by looking at how the risk and opportunities relate to an entities business model, strategy, governance performance and prospects, as part of broader sustainability and financial performance evaluation. In the UK the Transition Plan Taskforce aims to develop a gold standard for transition plans, encouraging entities to back up their net zero targets and other climate pledges with rigorous and credible short-term actions. This work includes both a framework and guidance on disclosure on transitions plans, which includes items on water usage, as well as impacts and dependencies on the natural environment (TPT, 2022^[71]).

Other disclosure standards include, the Sustainability Standards Board (SASB), that also published standards to guide the disclosure of financially material sustainability information by companies to their investors across 77 industries with a subset of ESG issues most relevant to financial performance in each industry. The World Economic Forum's International Business Council (WEF IBC) stakeholder capitalism

¹ More information: <https://www.fsb-tcfd.org/>

² More information: <https://www.ifrs.org/issued-standards/ir-framework/>

metrics³ also proposed a set of universal and material ESG metrics identified by the big four consultancy firms, to be used in mainstream annual reports of companies on a consistent basis.

In 2022, the formation of the International Sustainability Standards Board (ISSB), under the International Financial Reporting Standards (IFRS) Foundation, aimed to consolidate these approaches (including TCFD, Integrated Reporting, the SASB, and WEF IBC metrics) to provide standards for the Disclosure of Sustainability-related Financial Information and Climate-related Disclosures, with a focus on both financial materiality and impacts on the environment for an investor audience. In June 2023, ISSB published its first standards—IFRS S1 and IFRS S2. These standards respond to market demand for a more consistent approach to understanding how sustainability factors can reasonably be expected to impact on companies. The disclosure requirements laid out in IFRS S1 are designed to help companies to communicate to investors on the sustainability-related risks and opportunities they face, looking at the short, medium and long term. IFRS S2 is designed to be used with IFRS S1 and lays out climate-specific requirements. Both standards incorporate the recommendations of TCFD and help to create a common baseline for sustainability-related disclosures.

In parallel, the European Parliament and Council approved the Corporate Sustainability Reporting Directive⁴ (CSRD) to make businesses more publicly accountable for their societal and environmental impacts. CSRD introduces more detailed reporting requirements and ensures that large companies and listed SMEs are required to report on sustainability matters such as environmental rights, social rights, human rights and governance factors. This will come into force in four stages between 2025 and 2029 (Consilium Europa, 2022^[72]).

The European Financial Reporting Advisory Group (EFRAG) has proposed European Sustainability Reporting Standards (ESRS) to the European Commission for adoption. This guidance is for a multi-stakeholder audience (which includes investors) and is based on the concept of double materiality, expanding a company's reporting boundary to its entire value chain. ESRS would have a significant impact on the scope, volume and granularity of sustainability-related information to be collected and disclosed by companies (Jubels, 2022^[73]).

While recent initiatives, such as the ISSB, aim to converge disclosure and reporting frameworks towards more standardised approaches, this is still very much in early stages, and water-related risks are just one small part of these reporting frameworks. Lack of standardisation in how climate and environmental risks, including water-related risks, are assessed, reported, and integrated into investment and lending decisions remains a significant barrier (Jones and Jessop, 2021^[74]). Additionally, there is still large variation in the depth and breadth of corporates disclosure across assets and supply chain.

Recent developments are now drawing more attention to the importance of disclosure on nature in the financial system. This includes recent work under the Task-force on Nature related Financial Disclosure (TNFD), launched in 2021, of which the OECD is a knowledge partner, which develops recommendations that organisations can follow when disclosing information about the exposure of their companies to nature-related risks. By developing a risk management and disclosure framework for nature-related risks, the programme aims to help shift global financial flows away from nature-negative outcomes and toward nature-positive outcomes (TNFD, 2023^[75]). On 1st June 2023, the final draft TNFD beta framework publication was released for feedback, ahead of the publication of the full set of recommendations in September 2023 (see Figure 3.1) (TNFD, 2023^[75]).

³ More information: <https://assets.kpmg/content/dam/kpmg/xx/pdf/2021/03/wef-ibc-common-metrics-measuring-stakeholder-capitalism.pdf>

⁴ More information: <https://www.consilium.europa.eu/en/press/press-releases/2022/11/28/council-gives-final-green-light-to-corporate-sustainability-reporting-directive/>

Figure 3.1. TNFD Nature-related Disclosure Recommendations (v0.4)

Governance	Strategy	Risk & Impact Management	Metrics & Targets
Disclose the organisation's governance around nature-related dependencies, impacts, risks and opportunities.	Disclose the actual and potential impacts of nature-related dependencies, impacts, risks and opportunities on the organisation's businesses, strategy and financial planning where such information is material.	Disclose how the organisation identifies, assesses and manages nature-related dependencies, impacts, risks and opportunities.	Disclose the metrics and targets used to assess and manage relevant nature-related dependencies, impacts, risks and opportunities where such information is material.
Recommended Disclosures	Recommended Disclosures	Recommended Disclosures	Recommended Disclosures
A. Describe the board's oversight of nature-related dependencies, impacts, risks and opportunities. B. Describe management's role in assessing and managing nature-related dependencies, impacts, risks and opportunities.	A. Describe the nature-related dependencies, impacts, risks and opportunities the organisation has identified over the short, medium, and long term. B. Describe the effect nature-related risks and opportunities have had and may have on the organisation's businesses, strategy, and financial planning. C. Describe the resilience of the organisation's strategy to nature-related risks and opportunities, taking into consideration different scenarios. D. Disclose the locations where there are assets and/or activities in the organisation's direct operations, and upstream and/or downstream and/or financed where relevant, that are in priority areas.	A. (i) Describe the organisation's processes for identifying and assessing nature-related dependencies, impacts, risks and opportunities in its direct operations. A. (ii) Describe the organisation's approach to identifying nature-related dependencies, impacts, risks and opportunities in its upstream and downstream value chain(s) and financed activities and assets. B. Describe the organisation's processes for managing nature-related dependencies, impacts, risks and opportunities and actions taken in light of these processes. C. Describe how processes for identifying, assessing and managing nature-related risks are integrated into the organisation's overall risk management. D. Describe how affected stakeholders are engaged by the organisation in its assessment of, and response to, nature-related dependencies, impacts, risks and opportunities.	A. Disclose the metrics used by the organisation to assess and manage material nature-related risks and opportunities in line with its strategy and risk management process. B. Disclose the metrics used by the organisation to assess and manage dependencies and impacts on nature. C. Describe the targets and goals used by the organisation to manage nature-related dependencies, impacts, risks and opportunities and its performance against these.

Source: (TNFD, 2023^[75]) The TNFD Nature-related Risk and Opportunity Management and Disclosure Framework - Final Draft – Beta v0.4

The TNFD builds on existing initiatives that are trying to bridge the gap in nature-related disclosure. For example, CDP environmental disclosure includes a strong focus on water disclosure⁵, summarised in Box 3.1, which encourages companies to report on their water management practices and risks. These programmes aim to improve companies' understanding by reporting on water-related risks as well as water usage, water stewardship and water efficiency.

Similarly, a recent programme, known as the Valuing Water Finance Initiative, aims to develop and implement a new set of water-related disclosure frameworks for financial institutions beyond the existing TCFD recommendations. This initiative aims to provide a standardised approach to disclosing exposure to water-related risks to ensure investment, insurance, lending, rating and underwriting practices are well aligned, and to enable scoring and benchmarking. This initiative is summarised in Box 3.2 (Valuing Water Initiative, 2021^[76]).

⁵ More information: <https://www.cdp.net/en/water>

Box 3.1. CDP Environmental Disclosure

CDP is a non-profit organisation, which provides a global environmental disclosure system aligned with TCFD recommendations, and is also a knowledge partner to the TNFD, supporting the development of the TNFD framework. CDP's standards for corporate environmental reporting aim to help companies make their environmental impact transparent to stakeholders and provide a better understanding of how to reduce these impacts.

Through its disclosure system, CDP has a comprehensive set of environmental data available, including data on water-related risks, to capital markets to inform investment decisions, reduce investment risk, reward high-performing companies, and drive action towards environmental and climate objectives. At the same time, more disclosure helps accelerate the development of standard water impact metrics and performance benchmarks. This enables individual firms to benchmark their performance whilst also supporting tracking on global progress towards meeting environmental objectives, including sustainable use of water resources.

CDP's focus on water security is driven by corporate awareness of the need for a better understanding of water-related information to inform decision-making and drive effective action. CDP's 2020 climate change, water security and forests questionnaires showed that "less than 1% of disclosing companies were reporting nature-related risks, compared to 97% of those reporting risks related to climate" (IUCN, 2021^[77]).

With increasing water stress, pressure is growing for companies to build long-term resilience to water challenges into their businesses. As an illustration, in 2021, 68% of the 1 112 publicly listed companies disclosing on water via CDP reported that water risk drivers could generate a substantive impact on their business, up to USD 225 billion, while the cost of response was USD 119 billion.

To disclose on water related risks, companies and now financial institutions are requested to voluntarily complete an annual Water Security questionnaire, which helps them to better understand water risks and opportunities, facilitating informed decision making and improving long-term resilience. In addition, disclosure through CDP increases the transparency of water security and pollution reduction measures to shareholders and customers, helping companies improve their reputation. As mandatory disclosure gains momentum, voluntary disclosing through CDP also enables companies to develop internal reporting procedures and best practice, ahead of regulation.

Source: (CDP, 2022^[78]) Disclosing through CDP; (CDP, 2023^[79]) Water (CDP, 2022^[13]) High and dry

Box 3.2 Valuing Water Finance Initiative

The Valuing Water Finance Initiative is a new global investor-led effort to engage companies with a high water footprint to value and act on water as a financial risk and drive the necessary large-scale change to better protect water systems. The initiative calls on companies to meet Corporate Expectations for Valuing Water that align with the United Nations' 2030 Sustainable Development Goal for Water (SDG6) and the actions laid out in the Ceres Roadmap 2030.

This programme was launched by the Government of Netherlands leader of the Valuing Water Initiative, in partnership Ceres, a non-profit organisation working with capital market actors on sustainability issues, working in collaboration with a network of investors, companies and non-profits.

The Valuing Water Initiative works collaboratively with stakeholders, both inside and outside the water sector, to encourage governments, industries and civil society to bring about the systemic change required to understand, value and manage water resources, through the application of the UN Valuing Water Principles in different water value chains and sectors.

Building on this work, in 2022 Ceres' Valuing Water Finance Initiative was launched as a new global investor-led effort to engage 72 companies with a high-water footprint to value and act on water as a financial risk and drive the necessary large-scale change to better protect water systems. These companies, while at different stages of their water journeys, all have the potential to better steward and protect freshwater resources within their business operations and global supply chains to drive meaningful, global change. The initiative launched with a group of 64 signatories representing USD 9.8 trillion in assets under management.

Using new research and analysis as the foundation, the Valuing Water Finance Task Force, alongside investor and NGO partners, developed the Corporate Expectations for Valuing Water. This set of six, science-based, actionable expectations provide investors with a framework to engage with companies to strategically address water risk. These include:

- Actions to ensure current practices don't impact water quality and water availability
- Integration of water management into business processes, including board oversight and policy engagement
- Efforts to ensure access to the essentials – water and sanitation – across company value chains
- Protection of ecosystems is critical to the freshwater supplies that their businesses depend on

Source: (Government of Netherlands, 2023^[80]) The Valuing Water Initiative (Ceres, 2023^[81]) Valuing Water Finance Initiative

3.5. Supervisory guidance is being strengthened with more focus on climate and nature scenarios

Amongst key recommendations of the TCFD in 2017, was the use of scenario analysis as an important and useful tool for understanding the potential implications of climate change on organisations (TCFD, 2017^[82]). Scenario analysis can help investors, banks and insurance companies assess the potential financial impacts of different water related risks on company operations and financial performance.

In particular, scenario analysis is a key component of the supervisory review process, as it can help to assess risk management practices and the overall health of a sector. A comprehensive stress test under a range of hypothetical scenarios evaluates the bank or insurer's resilience to adverse economic conditions

and market shocks. Based on the risks identified, risk management frameworks can be designed to address risks through mitigation and investment strategies. Therefore, climate, and in the future nature, scenarios will be important tools for regulators to better understand exposure to water-related risks both in the short and long-term.

The NGFS aims to bring a global perspective on how the financial system can manage financial risks linked to climate and environmental factors. In particular, the NGFS work informs central banks and supervisors, as well as other financial sector participants, on the integration of climate-related risks.

Under the NGFS, an expert group of climate scientists and economists designed a set of exploratory scenarios to provide a common point for understanding how physical risk and transition risk could evolve under different contexts. This included a *Guide on climate scenario analysis for central banks and supervisors* (NGFS, 2020^[83]). Updated in 2022, these scenarios provide a range of higher and lower-risk outcomes to help central banks and supervisors explore the possible impacts of water-related risk on the economy and the financial system. This includes estimates of GDP losses from chronic risks that now more comprehensively account for model uncertainty and indicative illustrations of the way that acute physical risks could materialise over the course of the six scenarios (NGFS, 2021^[84]).

Climate scenario analysis remains a relatively new area for central banks and supervisors. Nevertheless, by 2022, 53 institutions from 36 jurisdictions across the Financial Stability Board (FSB) and NGFS membership were already undertaking climate scenario analysis exercises. For financial stability purposes, approaches to scenario analysis and stress testing will need to advance further in order to develop a truly system-wide approach. In particular, further work is needed to ensure these approaches cover key financial sectors, as well as interdependencies between risks and systemic risk factors, including indirect exposures, risk transfers, spillovers and feedback loops, including with the real economy (FSB, 2022^[85]).

Currently, climate change has been the key focus of this work. But efforts are now underway to better reflect nature, including biodiversity and water, broadening the scope from climate change. The NGFS acknowledges that “climate change itself is a source of environmental degradation and therefore, climate-related risks can be seen as a subset of broader environmental risks” (NGFS, 2022^[37]). It also recognises the potentially significant macroeconomic implications of nature-related risks, and that failure to account for, mitigate, and adapt to these implications is a source of risks relevant to financial stability (NGFS, 2022^[86]).

4 Sustainable finance initiatives can be taken a step further to address water-related risks

Water-related risks are fundamentally linked to key climate and nature challenges, including greenhouse gas emissions and biodiversity loss and decline. However, on average only 2% of sustainable finance mobilised annually between 2012 and 2020 has been directed towards water investments (OECD, 2023^[87]).

The financial sector is becoming increasingly proactive on climate issues, through aligning investment activities with climate goals or managing climate-related risks. There is also growing recognition of the impacts of human activities on nature, which require consideration both together with and independently from climate discussions. Water is at the heart of both the climate and the nature crises, and action on water should build upon existing efforts. Across many initiatives, there is scope for effort on climate to be taken one step further to be considered in a nature and water context. Recent developments are now drawing more attention to the importance of nature in the financial system, such as work under the NGFS and the TNFD.

In recent years, investors have increasingly taken actions to integrate climate change and broader sustainability concerns into their investment decisions and portfolio allocations. These actions fall under the scope of sustainable finance, which refers to the process of taking ESG considerations into account when making investment decisions in the financial sector, leading to more long-term investments in sustainable economic activities and projects (European Commission, 2023^[88]). More specifically, actions can also focus on green finance approaches, which include any structured financial activities, products and services that are designed to provide a better environmental outcome (WEF, 2020^[89]).

Various sustainable and green finance approaches have emerged to support investors in mobilising finance towards sustainable and environmental objectives, and away from activities that can exacerbate exposure to risks. Among these, ESG investing has become a leading form of sustainable finance and has progressed from early-stage development to mainstream finance. However, the relevance and effectiveness of sustainable finance initiatives for the water challenge is largely dependent on the quality and granularity of data and tools available.

4.1. ESG and climate risk scoring alone are not sufficient for assessing water-related risks

A range of market participants are increasingly integrating environmental factors in investment and risk management practices, notably in the context of the Environmental Pillar of ESG approaches. ESG metrics are used by investors to understand the performance of companies and to inform investment strategies, such as exclusionary screening or tilting, whereby companies are removed from the portfolio or conversely overweighted in the portfolio based on conflict or alignment on ESG issues. Other approaches include integrating ESG criteria, for example ESG risk metrics, alongside traditional financial analysis with a view

of how issues like climate change, social inequality and governance can affect a company's long-term performance. ESG scores and underlying metrics are also being used by central banks and financial authorities in their assessments of climate transition risks and progress in the financial system (OECD, 2022^[90]).

Assessments of water governance and exposure to water-related risk can fall under the environmental pillar of ESG analysis. A number of providers, such as Moody's⁶, S&P⁷, and MSCI⁸ provide ESG and climate scoring tools, that consider water stress as well as certain aspects of the company's management for water resources. This type of analysis is based on data on companies' exposure to water scarcity, flooding, and pollution, as well as their water usage and operations in areas prone to water-related risks, and water management policies and practices.

There remain notable challenges on the quality, comparability and availability of ESG data (OECD, 2020^[27]). Information is often self-reported by companies and may not be independently verified, which can weaken the reliability and consistency of data for analysis. This creates an important barrier to the integration of ESG risks and opportunities into investment processes (Jonsdottir et al., 2022^[91]). The assessment of water-related risk is therefore likely to be partial and have varying coverage across providers. In addition, methodologies developed to assess the alignment of finance with climate goals can often take different methodological approaches, as they are developed independently by research institutes and independent financial analysis entities (Noels and Jachnik, 2022^[92]). This can lead to a wide variation in results.

Similarly, climate scoring is increasingly used by regulatory bodies and financial institutions to have a clear picture of the climate change risk in their portfolio and future growth projections. Climate risk scoring aims to present a forward-looking view of an asset's exposure to a range of physical climate risks, including floods, heat stress, hurricanes and typhoons, sea level rise, water stress, and wildfires. This enables investors to look at specific risk drivers and identify companies that are more vulnerable to the impacts of climate change, such as those in sectors exposed to climate change driven water scarcity or flooding, as well as transition risks like those related to changing regulations, shifting consumer demand, or stranded assets.

However, climate risk scoring relies on various data sources, including company disclosures, external data providers, and sector-specific research and it is important to note that different companies and investors may use different methodologies to develop climate risk scores, which can lead to varying results. Critically, for water-related risks, climate scoring provides only a narrow approach. Increasing water demand in a basin, whether surface water or groundwater, can play a major role in water stress, irrespective of climatic circumstances. Likewise, climate scoring does not factor in pollution, or ecosystem or land degradation, which can further reduce water quality and availability.

4.2. Credit scoring does not yet fully capture water-related risk exposure

Credit scoring, which is a method used to evaluate the creditworthiness of businesses, is based on a variety of factors, such as credit history, income, and debt levels. Credit rating agencies, such as Moody's

⁶ More information: <https://esg.moody's.io/climate-solutions?>

⁷ More information: <https://press.spglobal.com/2022-09-15-S-P-Global-Sustainable1-Launches-Physical-Risk-Exposure-Scores-and-Financial-Impact>

⁸ More information: [https://www.msci.com/documents/1296102/16985724/MSCI-ClimateVaR-Introduction-Feb2020.pdf/f0ff1d77-3278-e409-7a2a-bf1da9d53f30#:~:text=Climate%20Value%20Dat%2DRisk%20\(change%20could%20affect%20company%20valuations](https://www.msci.com/documents/1296102/16985724/MSCI-ClimateVaR-Introduction-Feb2020.pdf/f0ff1d77-3278-e409-7a2a-bf1da9d53f30#:~:text=Climate%20Value%20Dat%2DRisk%20(change%20could%20affect%20company%20valuations)

and S&P Global, have a highly influential role in the financial system, impacting on the pricing of an issue or enabling the fast distribution of newly issued paper on capital markets without borrowers having to carry out their own credit risk assessment.

Identifiable climate-related risks that are relevant and material for the credit risk profile of the rated company can already be integrated into credit rating scores (NGFS, 2022^[93]). Credit scoring can therefore be an important tool for assessing a company's ability to manage water-related risks, and the potential implications of these risks on a business' ability to repay debt. For example, a business located in an area prone to flooding or drought may be considered to have a higher risk of defaulting on a loan.

Like challenges linked to ESG scoring, the relevance of credit rating scores for water-related risks, as well as any other climate or nature related risk, is directly dependent on the data and methodologies used. In this regard, credit rating agencies point to important challenges relating to the scarcity of consistent, granular and comparable climate-related data (NGFS, 2022^[93]). Given differing methodologies for assessing risks across credit rating agencies, and that these methodologies are not publicly disclosed, investors lack clarity and comparability in how climate risk factors are integrated into methodologies and how they contribute to the final rating (NGFS, 2022^[93]).

In addition, credit scoring can (and should) consider several different types of risk, of which water could be just one of many considerations. Methodologies used may also be ill adapted to assess the impact of water-specific challenges per se on credit worthiness.

An example of initiatives aiming to incorporate water risks into credit risk assessment methodologies can be seen in the "Corporate Bonds Water Credit Risk Tool", which supports financial analysts in quantifying corporate exposure to water stress and its potential impact on a company's credit ratios. The tool enables users to integrate financial risk exposure to water scarcity into standard financial models used to assess the credit strengths of corporates across water-intensive sectors including power utilities, beverages and mining. It does this by drawing on data on corporate water usage in various production locations combined with site-specific data on water supply and demand conditions (Ridley and Bolan, 2016^[94]).

Credit ratings play an important role in the financial system, including for central banks. Given their importance, central banks and market participants are working to develop and improve their climate risk assessment approaches (S&P, 2023^[95]). While at earlier stage, there is also increasing recognition of the need to strengthen tools to address nature risks in credit scoring (Agarwala et al., 2022^[96]).

4.3. Data is at the heart of the challenge for assessing water-related risks

Lack of standardisation and consistency in data and metrics used to evaluate water risks can make it difficult for financial actors to compare companies and sectors and to identify the most significant water-related risks and opportunities. The Global Risk Report 2021 by the World Economic Forum highlights that "Water-related risks are complex and can have cascading impacts on multiple sectors and regions" (WEF, 2021^[97]). A wide range of information is needed to understand risks across a company's value chains, including geospatial data on water resources, water stress, as well as water-related laws, regulations, and policies.

More broadly, concerns in relation to the lack of granular data for climate and nature are expressed in different parts of the financial system. For instance, Norges Bank Investment Management (NBIM) asset manager on behalf of the Ministry of Finance notes that "Access to relevant, high-quality data is limited. Unlike assessments of other types of risk, we can make limited use of historical data. There is also considerable uncertainty about the possible financial consequences of climate change and about the likelihood and timing of specific developments". This relates to climate and environmental risks, including water-related risks (NBIM, 2021, p. 3^[98]).

However, the market is moving rapidly, and the landscape of data platforms and sources is evolving. Data availability, quality and ease of use will be driven by the development of metrics and indicators, the growing adoption of nature-related targets in corporate strategy and reporting, and innovation of new tools, services and capabilities (TNFD, 2022^[99]).

Data on physical and transition risks come from a variety of sources, including government agencies, research institutions, and companies themselves. A recent discussion paper by the TNFD highlights that data and analytics coverage differs across nature realms, biomes and ecosystem types. Most tools and platforms do not have exhaustive data, which can result in bias towards most studied aspects and limit comparisons between regions (TNFD, 2022^[99]). For example, there are more data for terrestrial biomes than for marine or freshwater. Variances in measurement approaches also emphasises the need for standardisation. Nevertheless, there are already many data sources that can be used for assessing an organisation's dependencies on nature and the impacts of its operations on the environment (TNFD, 2022^[99]) (see Table A A.1.).

Corporate non-financial information, for example, on water usage, wastewater management and water stewardship initiatives, plays a crucial role in assessing financial and impact materiality. Recent briefs by CERES on the apparel and meat industries highlight that assessments of exposure to water-related externalities throughout a value chain can already be made (Ceres, 2021^[100]; Ceres, 2021^[101]). The case of the packaged meat industry (seen in Box 4.1) shows how this exercise can quantify potential costs and guide corporates towards determining the necessary capital and operational investments to mitigate impact materiality, minimise potential losses, and leverage opportunities in response to growing water challenges (Ceres, 2021^[101]).

As discussed above, more consistent and transparent public disclosure on water security can help corporates and other financial sector actors identify new investment opportunities to avoid the costs of water-related events or access new water-related markets. In addition, public disclosure frameworks increase the amount of data on water-related risks available in the public realm to develop metrics and performance benchmarks, whereas much of the analysis on climate and environment risks has been produced and owned by private actors. As an illustration, Four Twenty-Seven (427), a key climate research and data provider, which produces physical risk guidance to the financial sector, was acquired by Moody's, one of the largest credit rating agencies. This can create an asymmetry of information between private actors and regulators that hampers the effectiveness of policies.

Box 4.1. Addressing the financial implications of addressing water-related externalities in the packaged meat industry

Valuing water is important for investors

Current approaches to assessing water risk fail to consider the potential financial losses resulting from companies' negative impacts on water resources. This oversight exposes companies and investors to higher-than-expected losses.

In the packaged meat industry, there are numerous water-related practices and externalities that have chronic and systemic effects on freshwater resources. CERES conducted a study to identify and map these externalities throughout the value chain of the packaged meat industry (Table 4.1).

Table 4.1. Externalities associated with the packaged meat industry identified from scientific literature and subject matter experts

Value chain section	Activity	Externality	Freshwater Impact	Business Risk Examples
Grain for feed production	Fertiliser applications	Nutrient loading	Eutrophication	Increased cost of grain/feed
	Irrigation	Water withdrawals	Water stress	
	Pesticides and herbicide applications	Pesticide and herbicide runoff	Toxicity for aquatic life	
	Land conversion and deforestation	Sedimentation and salinity	Suspended solids, toxicity for aquatic life	
Animal raising	Manure	Nutrient loading	Eutrophication	Increased CAPEX/OPEX to access alternative water supply
	Livestock drinking and service water	Water withdrawals	Water stress	
	Manure disposal	Pharmaceuticals; and Lagoon leakage and overflow	Inhibition of microbial and bacterial growth, bioaccumulation in aquatic life, eutrophication	
	Livestock grazing	Overgrazing	Suspended solids	
Animal processing and packaging	Processing water discharge	Wastewater discharge	Eutrophication, toxicity for aquatic life, inhibition of microbial and bacterial growth, bioaccumulation in aquatic life	Litigation over impacts on downstream water quality or groundwater depletion
	Processing water use	Water withdrawals	Water stress	
Distribution	Retail water use	Water withdrawals	Water stress	Loss of social and legal license to operate
Consumer use	Product packaging	Use and discard of plastic packaging	Impact on aquatic life	

Pricing of water-related externalities in the packaged meat industry

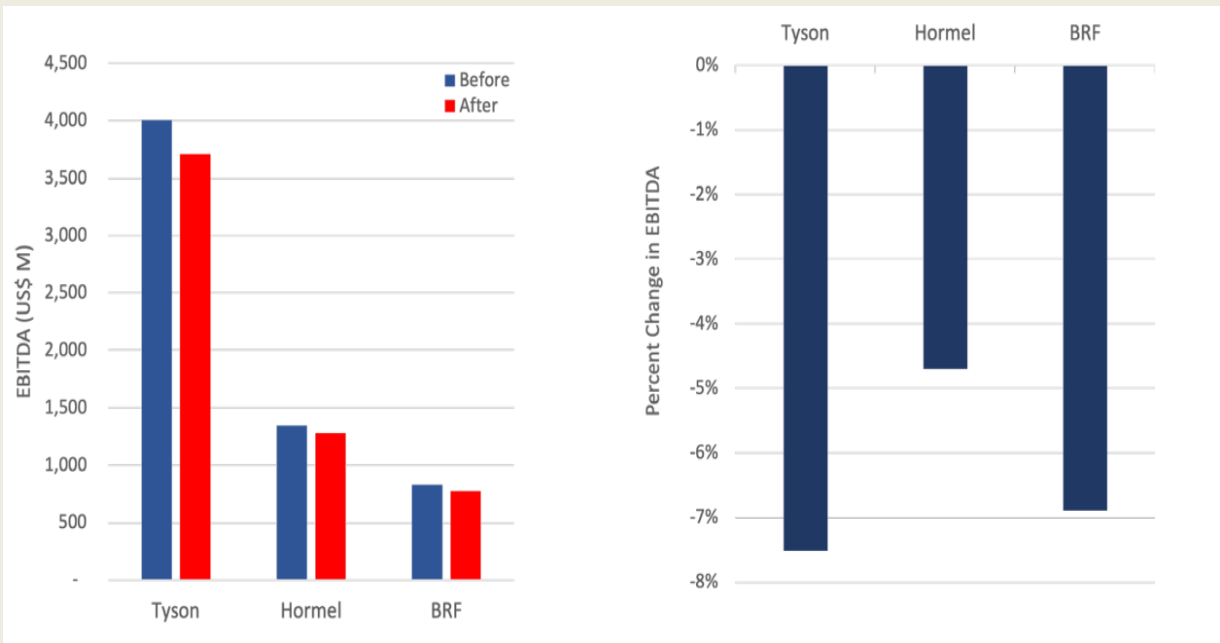
BRF S.A., Hormel Foods Corporation, and Tyson Foods Inc. were selected to evaluate the impact of water-related externalities. These companies collectively generated sales of USD 60 billion in 2019 and had a market capitalization of USD 55 billion. The study estimated the annual costs required for each company to eliminate its externalities using DWS's Cash Return on Capital Invested (CROCI) Framework. The results revealed that BRF, Hormel, and Tyson would need to spend approximately USD 57.3 million, USD 63.2 million, and USD 301.4 million respectively to address their impacts on freshwater. These estimates are high level and conservative and the actual cost would be likely to be much higher.

For context, large companies, usually allocating about 3.2% of their revenue on technology, would only need to spend less than one-third of that amount to eliminate their negative impacts on water resources in

the packaged meat industry. This action would help mitigate water-related risks and improve water availability and quality.

The financial impact of these additional costs varied across the companies. While Hormel and Tyson experienced modest effects on EBITDA and CROCI, the impact on BRF was significant due to its lower profitability and higher valuation in 2019 (Figure 4.1). BRF's net profit was estimated to decrease by 165% as a result of the required expenditures.

Figure 4.1. Impact of the annual cost to address externalities on EBITDA in USD M and as a percent change, based on the 2019 annual currency conversion rate



Findings

The study demonstrates that it is feasible to estimate water-related externalities across the value chain when companies have access to operational and procurement data.

The significance of relying on grain in the packaged meat industry lies in the fact that over 90% of water consumption in water-scarce regions occurs on irrigated farms, with 20% of that irrigation relying on non-renewable groundwater.

Investors should closely monitor corporate disclosures to ensure that companies prioritise actions in the most impactful areas of the value chain, considering the contextual challenges faced by each company's operating and sourcing locations. The methods used in this study can be applied to other sectors to estimate their impacts on water resources, determine the required expenditures to mitigate these impacts, minimise value at risk, and seize opportunities in the face of growing water challenges.

Note: Earnings before interest, taxes, depreciation, and amortization (EBITDA), United States Dollars (USD), Millions (M)
Source: (Ceres, 2021^[101]) Financial Implications of Addressing Water-Related Externalities in The Packaged Meat Industry

4.4. Green taxonomies can help mainstream water in green finance

Green finance presents an opportunity to direct flows towards achieving environmentally sustainable goals, such as water security, and direct flows away from exacerbating environmental challenges, including water pollution. However, the effectiveness of such initiatives is face with challenges linked to ‘internalising environmental externalities, information asymmetry, inadequate analytical capacity and lack of clarity in the definition of “green”’ (Berensmann and Lindenberg, 2016^[102]).

A number of jurisdictions have started to legislate to create official definitions of sustainable finance (OECD, 2020^[103]). For environmental challenges, green taxonomies are emerging as an important system for classifying environmentally sustainable activities, including those related to water resources. For example, the “EU Taxonomy”⁹, has set specific climate and environmental priorities that sustainable activities must align with. This includes climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems. To be taxonomy-compliant, an economic activity needs to contribute substantially to one or more of these objectives, comply with technical screening criteria established by the Commission through delegated acts, Do No Significant Harm (DNSH) to any other environmental objective, whilst also complying minimum social safeguards (ECB, 2020^[35]).

Through a clear identification and common understanding of sustainable investments, taxonomies aim to provide greater clarity and certainty for both investors and issuers and the EU approach aims to provide more certainty on the alignment across environmental goals, through screening and DNSH criteria. Many green taxonomies around the world apply a similar approach, although they may vary on specific objectives, coverage, metrics and thresholds.

Green taxonomies that include a water-related objective can provide new opportunities to direct the flow of investment capital towards projects that contribute to water security and limit the risk of greenwashing. Using a multi-criteria approach provides an important tool for avoiding misalignment of green investments across sustainable development objectives. For example, while a hydropower plant can contribute to mitigation efforts, under certain conditions, it can have a detrimental impact on environmental objectives by disrupting freshwater resources or leading to biodiversity loss.

In addition, in the European context, the EU Taxonomy will provide a common framework for other sustainable finance regulations such as the EU Green Bond Standard, EU Ecolabel, Markets in Financial Instruments Directive (MIFID) sustainability preferences, company reporting by entities covered by the CSRD, and sustainability disclosures for “sustainable investments” under the SFDR.

Published in June 2023, the Environmental Delegated Act¹⁰ now provides screening criteria for the sustainable use and protection of water and marine resources, as well as the other three environmental objectives. Criteria across the four objectives will be highly relevant, given that water-related projects can support multiple environmental goals. For example, nature-based solutions or integrated watershed management can improve water quality, biodiversity and pollution control at the same time (OECD, 2020^[103]). Box 4.2 provides an overview of economic activities that are covered by the green taxonomies screening criteria as contributing substantially to the sustainable use and protection of water and marine resources.

Having only recently been published, it is too early to speak to implementation challenges of the Environmental Delegated Act. It is worth noting however, that certain key sectors, such as the agricultural sector, will not be covered by screening criteria, which can leave some high impact activities invisible to the green taxonomy system.

⁹ More information: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R0852>

¹⁰ More information: https://finance.ec.europa.eu/publications/sustainable-finance-package-2023_en

Box 4.2. EU Taxonomy Environmental Delegated Act - Annex I on sustainable use and protection of water and marine resources

Activities covered in Annex I on sustainable use and protection of water and marine resources

1. Manufacturing
 - Manufacture, installation and associated services for leakage control technologies enabling leakage reduction and prevention in water supply systems
2. Water supply, sewerage, waste management and remediation activities
 - Water supply
 - Urban Wastewater Treatment
 - Sustainable urban drainage systems (SUDS)
3. Disaster risk management
 - Nature-based solutions for flood and drought risk prevention and protection
4. Information and communication
 - Provision of IT/OT data-driven solutions for leakage reduction

Example criteria for manufacture, installation and associated services

Screening criteria

1. The activity manufactures, installs or provides maintenance, repairs or professional services for leakage control technologies in new or existing water supply systems, aimed at controlling the pressure in district metered areas of the water supply system to a minimum pressure.
2. Environmental degradation risks related to preserving water quality and avoiding water stress are identified and addressed with the aim of achieving good water status and good ecological potential as defined in Article 2, points (22) and (23), of Regulation (EU) 2020/852, in accordance with Directive 2000/60/EC¹ and in line with a water use and protection management plan, developed in accordance with that Directive for the potentially affected water body or bodies, in consultation with relevant stakeholders.

Do no significant harm ('DNSH') criteria

1. Climate change mitigation: N/A
2. Climate change adaptation: complies with generic criteria for DNSH to adaptation detailed in Appendix of Annex
4. Transition to a circular economy: assesses the availability of and, where feasible, adopts techniques that support:
 - reuse and use of secondary raw materials and reused components in products manufactured;
 - design for high durability, recyclability, easy disassembly and adaptability of products manufactured;
 - waste management that prioritises recycling over disposal, in the manufacturing process
 - information on and traceability of substances of concern throughout the life cycle of the manufactured products.
5. Pollution prevention and control: complies with generic criteria for DNSH set out in Appendix C of Annex.
6. Protection and restoration of biodiversity and ecosystems: complies with generic criteria for DNSH set out in Appendix D of Annex

Source: (European Commission, 2023^[104]) Annex I: Sustainable use and protection of water and marine resources

4.5. New tools for assessing and addressing water-related risks are emerging

Water-related risk is a complex and multi-faceted issue for companies and investors. In general, the understanding of financial risks associated with water and biodiversity is in relatively earlier stages than climate risks. Assessments of water-related risks require resources and expertise and are dependent on availability of data for conducting a comprehensive analysis.

Nevertheless, a range of tools have started to emerge, which can help investors make initial assessments of the financial materiality of water-related risks when making investment decisions (as seen in Table A A.1.). Dedicated tools which increase both corporate and investors understanding of water risks can have an important role engaging and stimulating collective action to mitigate water-related risks and develop strategies at local level.

This can be done through a number of methods. Simplified scenarios, for example, are an important tool for providing a forward-looking vision of risks. The WWF Water Risk Filter provides assessments on water risk exposure to the financial impacts of severe droughts, flooding buildings on climate and socio-economic scenarios (WWF, 2020^[105]). The Inevitable Policy Response (IPR) by Principles for Responsible Investment (UN PRI) looks more specifically at how policy trajectories in the short and long term (transition risks) across all major countries/regions will impact investors (PRI, 2022^[106]). It is important to note that these scenarios can often show only a partial picture. The relationship between climate change and potential second-order effects is highly complex and so difficult to estimate (IPCC, 2013^[107]).

Other tools can help financial institutions assess their exposure to natural capital risks, through the measurement of dependencies and impacts. The United Nations Environment Programme Finance Initiative (UNEP-FI) proposes the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) tool, which was developed by the Natural Capital Finance Alliance (NCFA) in partnership with UNEP World Conservation Monitoring Centre (UNEP-WCMC). It provides general information on natural capital broadly, with a strong focus on biodiversity as well as other natural resources such as water, air, and soil (NCFA, 2018^[108]). Its focus on issues such as water scarcity or quality, soil erosion, and other ecological factors, helps financial institutions to better understand their dependencies and impacts on natural capital and develop strategies to manage them effectively. It has notably been used by DNB, the Banque de France and the Central Bank of Malaysia (BdF, 2022^[109]; BNM, 2022^[110]; DNB, 2020^[111]).

Other tools are more specifically targeted towards providing quantitative and qualitative tools to investors, including institutional investors and asset managers. These can equip them with information and resources to assess how water-related risk can materially affect corporations and how to integrate water risk into investment decisions. For example, as summarised in Box 4.3 the Ceres Investor Water Toolkit, was developed in collaboration with institutional investors, and provides learning material, databases, case studies and other tools to inform investment decisions (Ceres, 2023^[112]). Other tools target businesses to help them assess water-related risks and understand the gap between what is being paid for water, its value for operations and the potential costs of water risks. In this regard, the ECO Lab enhanced Smart Water Navigator, provides a Water Risk Monetizer tool to evaluate the potential costs of water. This is also combined with a Water Action Assessment tool to provide guidance on proportionate action at local level to mitigate risks (EcoLab, 2022^[113]). By gaining a better understanding of the materiality of water-related risks, investors can better understand the corresponding value or cost of implementing mitigations measures.

Box 4.3. Ceres Investor Water Toolkit

Ceres is a non-profit organisation working with capital market actors on sustainability issues, working in collaboration with a network of investors, companies and non-profits. Ceres provides market-based and policy solutions across a range of sustainability topics, including water. This includes interactive tools and research to educate and encourage companies and investors across sectors of the economy to take sustainability action. For example, Ceres has recently published analysis contributing to the body of research on the financial materiality of water-related risks in the meat and apparel sectors.

The Investor Water Toolkit is designed to help investors manage these risks. Developed in collaboration with more than 40 institutional investors from the Ceres Investor Water Hub, a working group of Ceres Investor Network, it is the ultimate investor resource on water risk integration in portfolio management. The guides are designed to help investors to evaluate water risks across all asset classes and design strategies for mitigating water risks in their investment portfolios. The Toolkit is designed to:

- Help investors comprehensively understand water risk drivers
- Create a one-stop platform that allows institutional investors to integrate water across the decision-making value chain, from asset class analysis to portfolio characterization, to buy/sell decision making
- Provide stand-alone guides, resource lists and databases on specific topics or asset classes, including equities, municipal bonds and private equity
- Provide case studies written by investors that showcase real life water risk integration practices
- Evolve and capture new ideas through on the dedicated webpage (www.ceres.org/investorwatertoolkit).

Source: (Ceres, 2018^[114]) Investor Water Toolkit; (Ceres, 2021^[100]) Financial Implications of Addressing Water-Related Externalities in the Apparel Sector; (Ceres, 2021^[101]) Financial Implications of Addressing Water-Related Externalities in the Meat Sector | Ceres

Further initiatives can help corporates determine a pathway for reducing their impact on nature and climate change. For greenhouse gas emissions, the Science-Based Targets initiative (SBTi) has supported corporates in developing science-based targets to determine a clear pathway to reducing emissions in line with the goals of the Paris Agreement. These targets align with the latest climate science and aim to limit global warming to below 2°C above pre-industrial levels, with efforts to limit it to 1.5°C.

Following the Kunming-Montreal Global Biodiversity Framework, finalised in December 2022, science-based targets for nature have been identified as a key mechanism for supporting the implementation of Target 15 which focuses on the role of business and managing and disclosing its impact on nature. In 2023, Science-Based Targets for Nature (SBTN) was launched to support companies in measuring and addressing their environmental impacts across their value chains using the best available science. It aims to support companies in comprehensively assessing their environmental impacts and improving their overall sustainability, targeting activities to avoid and reduce their impacts, such as deforestation and pollution, but also how to increase sustainability, including through watershed restoration and rehabilitating degraded land (see SBTN freshwater guidance in Box 4.4) (SBTN, 2023^[115]).

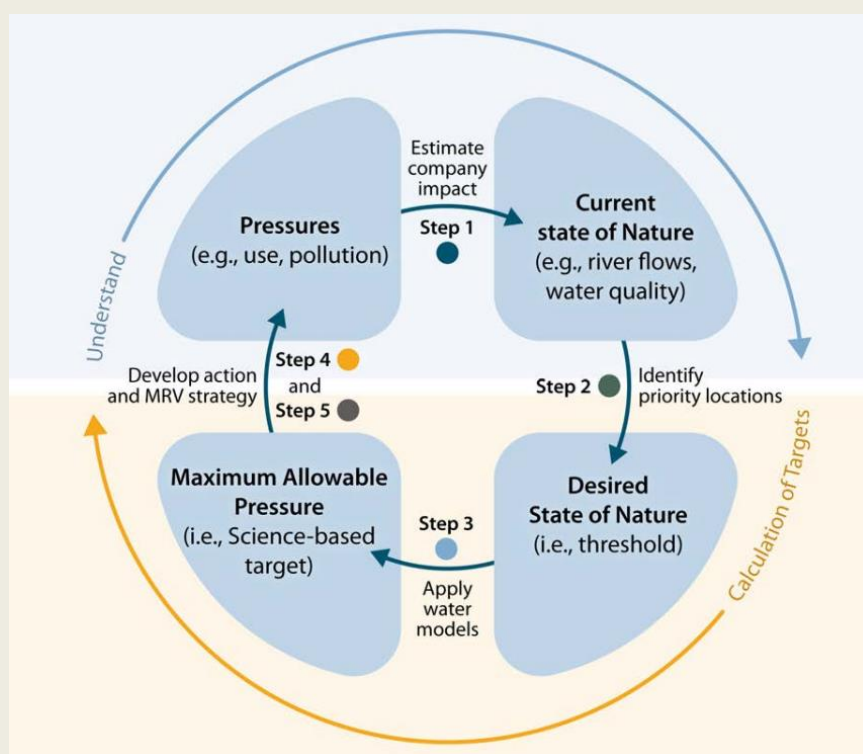
Box 4.4. SBTs for nature - guidance for freshwater

Science-based targets (SBT) for nature are based on a framework assessing underlying Drivers, Pressures, States, Impacts, Responses. These are considered under a 5-step process:

- Step 1: Assess—screen and estimate impacts
- Step 2: Interpret and Prioritize—set target boundary and prioritise
- Step 3: Measure, Set and Disclose—set and validate targets
- Step 4: Act—develop action strategy; and
- Step 5: Track—Measurement, Reporting and Verification (MRV)

This process is illustrated in Figure 4.2. In steps 1 and 2, companies screen economic activities for materiality, conduct a location-specific assessment of pressures and states, and define target boundaries for each pressure with the relevant SBT methodology for target-setting. Companies must also prioritise locations to set targets. In step 3, specific SBT guidance for freshwater is applied to set and validate targets for quantity or quality. This requires specific indicators to represent the pressure(s) and state of nature, a threshold value representing the desired state of nature, and a method to relate the desired state of nature to the level of pressure. Using pollution as an example, the target would define, for each basin, the maximum amount of pollutants that a company could discharge while maintaining acceptable fresh.

Figure 4.2. High-level overview of the five steps in the target setting process as applied to freshwater



Source: (SBTN, 2023^[116]) Technical guidance step 3: Freshwater

5 Areas for further research

Interest in the financial materiality of water-related risks has evolved rapidly over the last few years. Yet, a review of current practices indicates that this materiality is not yet fully captured in current risk assessment approaches used by central banks and financial institutions (OECD, 2021^[6]). There is growing recognition that the financial sector is potentially materially exposed to water-related risks and this exposure, particularly to physical risks, is not fully understood (Coloia and Jansen, 2021^[7]; ECB, 2022^[8]).

The apparent disconnect between the economic and financial materiality of water-related risks is an important consideration for policymakers and financial regulators. If financially material water-related risks are invisible to current analytical approaches used in the financial system, when risks materialise, financial actors may not be equipped to deal with them.

Moreover, it is becoming clearer that nature-related risks, including those linked to water, have potentially significant macroeconomic implications, and that failure to account for, mitigate, and adapt to these implications is a source of risk relevant to financial stability (NGFS, 2022^[86]).

As noted by Mark Carney, the tragedy of the time horizons is such that climate and environment risks outspan the timelines of central banks. “The horizon for monetary policy extends out to 2-3 years. For financial stability it is a bit longer, but typically only to the outer boundaries of the credit cycle – about a decade “ (Bank of England, 2015^[117]). While some early progress is being made on the climate agenda, central banks’ understanding of environmental and particularly water-related risks is still limited, as are approaches to assessing the implications of water related risks implications on financial stability and price stability.

Some finance supervisors have started to provide guidance on the integration of water-related risks in financial system risk assessments, but regulation does not yet mandate thorough analysis of exposure to water-related risks. Recommendations from the TCFD and the NGFS take a step in the right direction to push the financial sector towards analysing financial materiality. However, the financial system appears to be slow in its uptake of the assessment of those risks, and many institutions continue to rely on historical rather than forward-looking data, despite evidence that risks are present and increasing. Those that have made assessments, however, are highlighting potential exposure to water-related risks (CISL, 2022^[118]).

Certain central banks, such as the Central Bank of the Netherlands, are leading the way, with initial stress testing of the financial sector’s exposure to water-related risks. However, these assessments point to notable data gaps and methodological challenges, suggesting that regulators and central banks still have only an emerging understanding of exposure to water risks, which can only be reflected in gaps in supervisory guidance and prudential regulation (Coloia and Jansen, 2021^[7]).

There are recent examples of actions that can already be taken to assess and address water-related risks amongst investors and corporates (Box 4.3). In addition, there are a few new studies which are starting to explore water-related risk drivers and transmission channels to financial institutions (see Box 2.1), but in general this literature remains limited. Consequently, there is limited guidance to financial institutions on how to identify and assess water-related risks within their portfolios. Moreover, at supervisory level, risk assessments are limited by lack of available micro level literature and data.

An effective policy approach to financial stability requires a framework that allows for an effective analysis and monitoring of micro and macro dimensions within financial systems. “In the highly interconnected and complex structure of today’s financial system, risks that arise at the institutional level can have system-wide dimensions. As such, risks cannot necessarily be identified through aggregated data, more granular information is needed” (BIS, 2015^[119]). This means that both micro and macro dimensions should be looked at in ways that are parallel, harmonised and complementary.

This points to an important need for strong collaboration between the environmental community and the financial community to improve the collective understanding of how water-related risks translate into financial risk at various levels, and to develop the necessary tools and data to assess financial materiality. In particular, the water community can engage with finance supervisors to bridge the data and methodological gaps that may prevent a quick uptake of water-related risk assessments by the financial system.

The general approach to risk assessment in the financial system is a granular individual asset risk level approach. Lack of data is a limitation to properly assessing water-related risks, as well as, more generally, environmental and climate-related risks. This is increasingly recognised as an issue for the financial sector. There is a need for better data and better risk assessment methods to better understand and manage the risks associated with water. In this context, areas for further work should aim to strengthen water-specific analysis, whilst also exploring how this can inform and strengthen integrated guidance, notably ensuring that water is a well-identified feature of the broader nature agenda. The following areas are particularly important:

- Improving **disclosure standards** for water-related risk is critical to improving investors understanding of risks and enabling relevant data to consistently be included in risk assessments. Notably, the TFND should bring a strong focus to water in its guidance to central banks, insurers and investors.
- There is a growing number of data sources and tools that aim to guide corporates and investors in their understanding of the materiality of water-related risk. A comprehensive overview of resources that are already available would be of benefit to the water community. This includes a review of **current limitations and next steps for risk assessment tools** in seeking to translate water-related risk into financial risks.
- Guidance should be strengthened through further **analysis and use cases** focused on micro-level exposure to water-related risks in specific sectors, as well as business decisions which can mitigate or increase exposure to water-related risks, reflecting the importance of considering both financial and impact materiality. This analysis would contribute to sector-specific guidance to investors on the identification and assessment of water-related risks across the value chain. In addition, this work can contribute to informing macro level assessments, by strengthening existing literature on transmission channels for water-related risk at sector level.
- In addition, **supervisory guidance on exposures, impacts and dependencies to water-related financial risks within the financial system** should be strengthened to improve oversight and management of such risks. A mapping of existing tools and resources, and guidance on transmission channels, metrics and indicators specific to water-related risks, can contribute to guidance to governments, central banks and other regulators. This work can also inform recommendations on integrating assessments of water-related risks under current supervisory guidance frameworks.
- The use of risk assessment tools and data to spur **on collective action and engagement between corporate and investors** on water-related risks is critical. These risks are not static and the importance of engagement with stakeholders to identify and mitigate risks at local level should not be understated.

- Research points to the importance of the **insurance sector**, which plays a critical role in determining the financial materiality of water-related risks. Insurance regulation, however, has a less cohesive international framework than the banking sector. Nationally different regulation will govern companies and inform how water-related risks are assessed and priced. There is a danger that simply reflecting rising water-related risks through higher insurance premiums could lead to a growing coverage gap and increased exposure to risks. There may be an important role here for identifying best practices in assessing water risks, as well as approaches to managing and mitigating water-related risks, alongside insurance. This includes the role of government in risk-sharing as seen with the Water RE programme in the UK.
- Previous OECD research points at gaps in the assessment of the potential impact of water-related risks on **bank premises**, including data centres and offices, and including the risk assessment in the prudential reporting, which as per ECB guidance would seem a relatively quick win. It could also contribute to enhancing the water-related risks culture within banks, opening the way for a larger update of risk assessment tools beyond the operational risk (OECD, 2021^[6]).
- In addition, sovereign borrowers are a large part of banks' credit exposures. Research highlights that there are reasons to believe that **sovereign borrowers**, or some of them, may be highly exposed to water-related risks, and that this exposure has not been fully priced in by financial markets (OECD, 2021^[6]).
- Research points at gaps in the assessment of the financial materiality of water-related risks for **sovereign and municipal issuers**, which together form a substantial part of new issuance and stocks of debt on capital markets. The water community could be instrumental to bridging this gap by considering not only the economic implications of policy action but also its potential financial impacts. While this role has been traditionally devoted to financial analysts such as those employed in CRAs, water-related risks are a new area of investigation for the financial sector. Enhanced dialogue between the water and the financial community on financial impacts could help bridge the existing materiality gap. It could also increase the information channels of the water community on which type of policy action is considered as a mitigant by the financial sector from the point of view of financial impacts (strong regional planning, robust storage and conservation efforts in the above example), which could help prioritise investment (OECD, 2021^[6]).
- On a more general level, water policies, regulations and management practices directly impact the water security of municipalities, regions and countries. Physical, economic and financial water-related risks are also driven by policies in other sectors (agriculture, urban development and housing, land use, and energy, among others). In this respect, the water community also needs to **engage with other communities** to mitigate water-related risks. Therefore, these actions directly affect the financial impacts of water-related risks on sovereigns and municipal issuers. Investments to improve water security can be a key factor in mitigating financial risk (notably in the short-term credit risk of states and local water utilities) (OECD, 2021^[6]).

Annex A. List of tools and data for assessing financial materiality of water-related risks

Table A A.1. Non-exhaustive list of data sources and tools for freshwater water-related risks

Tools	Description
Collect Earth	Satellite imagery viewing tool. Specialty in monitoring land use change
Ecolab Water Risk Monetizer	Quantifies the full value of incoming and outgoing water to a specific location based on basin-level quantity and quality considerations.
EcoVadis	Access ESG ratings upstream and downstream in the value chain, for a range of organisations engaged with the tool.
GEMI Local Water Tool	Evaluate the external impacts, business risks, opportunities and management plans related to water use and discharge at a specific site or operation
RBA Country Risk Assessment Tool	Identify inherent risks within supply chains.
SEDEX RADAR Tool	Identify inherent risks within supply chains, including Water and 13 other potential issues, based on geography and sector.
Water Footprint Network Assessment Tool	Quantity water consumption and sustainability based on geography and use data.
WRI Aqueduct - Water Risk Atlas	Identify and evaluate water risks based on geography, including geospatial data of water-stressed regions that can be overlayed with operations/supplier locations.
WWF Water Risk Filter	Explore water risks (physical, regulatory, reputational), assess these across the value chain, and identify potential mitigation actions.
Exiobase	Multi-regional environmentally-extended input-output databases can be used to estimate environmental impacts based on sector and geography. Can also be used to estimate supply chain sector/geography breakdown, and relative impacts.
Ecoinvent	Life Cycle Inventory (LCI) data to support sustainability assessments such as Life Cycle Assessments (LCA). This data can be used to support quantification of impacts throughout the life cycle stages of a product or service.
FAO/ AQUASTAT	A tool that collects, analyses and provides free access to over 180 variables and indicators by country from 1960
India Water Tool	Specific to India, this geospatial tool provides access to water-related datasets and risk indicators.
Maplecroft Global Water Security Risk Index	Access to the Water Stress index that evaluates total water use relative to annual available flow on a catchment level across the globe, enabling users to assess inherent water stress in a particular business location.
ENCORE	Geospatial datasets on natural capital assets and drivers of environmental change, and qualitative impact/ dependency ratings that link ecosystem services to production processes.
FAO WaPOR	Indicator for selected regions, showing the annual Gross Biomass Water Productivity expressed as the quantity of output (total biomass production) in relation to the total volume of water consumed in the year (actual evapotranspiration).
Global Wetlands geospatial data	Geospatial wetland data, searchable by country and type of wetland
Freshwater Ecosystems Explorer	Understand the state of fresh water ecosystems, in geospatial time-series data that is considered accurate, up-to-date, high-resolution.
Natural and Mixed World Heritage Sites data	Geospatial data for UNESCO World Heritage sites that can be overlayed with operations/supplier locations, to screen for sites that sit in these locations.
IBAT	Geospatial data to identify where operations/supplier locations sit in areas of interest such as Key Biodiversity Areas.
RepRisk controversy data	Third-party controversy data on a range of ESG topics, to support tasks such as materiality assessments, due diligence and monitoring

Tools	Description
Rezatec Geospatial AI	Geospatial AI data that enables remote monitoring of water infrastructure and water catchment areas, water quality, pipeline risk etc. Aside from Water, there are also datasets available for Forestry, Agriculture and Energy.
Swiss Re's CatNet	Geospatial tool to identify and assess natural hazard risk, including the Biodiversity and Ecosystem Services (BES) index.
Biome geospatial data from National Geographic Tool	Visual map of biomes, to support identification of relevant biomes that operations/supply chains impact and/or depend on.
Copernicus	Synthetic Aperture Radar (SAR) Analysis Ready Data (ARD) on land use mapping, including hotspotting of environmentally stressed areas.
Global Risk Assessment Services (GRAS)	Third-party assessments using GIS and remote sensing technologies to move toward transparent and deforestation-free supply chains.
Preferred by Nature - Sourcing Hub	Identification of risks e.g. through the use of the Timber Risk Score that provides country-level qualitative scores on the potential extent of illegal timber practices.
Beef on Track	Platform collating systems, tools, data and technical information to support organisations in creating a deforestation-free beef chain in the Amazon
Starling satellite imagery	Satellite imagery tool to support supply chain impact assessments on deforestation.
Proforest	Commodity-specific toolkits that can support organisations to map out forest-related risk in supply chains.
AFi	Guidance on transparency within forestry and agricultural commodity supply chains.
Science-Based Targets for Nature	The SBT for Nature guidance provides sector and subindustry guidance on identification of direction operation and wider value chain impacts. Note that the guidance for SBT for Nature is currently in consultation and will be updated over time.
Environmental Justice Atlas	Can be used to map socio-environmental conflicts, and understand key socio-environmental risks related to forest-risk commodity production in specific regions
Global Forest Watch	Geospatial data for monitoring companies and portfolios in forest-risk commodity supply chains. Can be used to build understanding of the extent of deforestation in forest-risk commodities and financing, focusing on the state of forests and the pressures.
Land Portal Geoportal	Geospatial data layers on forest tenure, land and corruption, forest landscape restoration and indigenous and community land rights.
MapBiomass	Historical land cover and land use data, covering Brazil, the Amazon and the Gran Chaco. Allows visibility of deforestation over time.
Trase	Maps forest-risk supply chains linking consumer countries and traders with places of production. This allows greater visibility of the countries, regions and companies that have higher rates of deforestation.

Source: (TNFD, 2022^[99]) Discussion paper: A Landscape Assessment of Nature-related Data and Analytics Availability

References

- 427 (2020), , <https://www.preventionweb.net/publication/measuring-what-matters-new-approach-assessing-sovereign-climate-risk>. [46]
- Adams, C. et al. (2021), *The double-materiality concept Application and issues*, Global Reporting Initiative (GRI) , London, <https://www.globalreporting.org/media/jrbntbyv/griwhitepaper-publications.pdf> (accessed on 10 January 2023). [26]
- Agarwala, M. et al. (2022), *Nature loss and sovereign ratings*, <https://www.bennettinstitute.cam.ac.uk/wp-content/uploads/2022/06/NatureLossSovereignCreditRatings.pdf>. [96]
- APRA (2022), *APRA publishes findings of latest climate risk self-assessment survey* | APRA, The Australian Prudential Regulation Authority (APRA), <https://www.apra.gov.au/news-and-publications/apra-publishes-findings-of-latest-climate-risk-self-assessment-survey> (accessed on 11 January 2023). [65]
- Bank of England (2015), *Breaking the tragedy of the horizon climate change and financial stability*, <https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability>. [117]
- BdF (2022), *A “Silent Spring” for the Financial System? Exploring Biodiversity-Related Financial Risks in France. Working Paper Series no. 826.* [109]
- Berensmann, K. and N. Lindenberg (2016), *Green Finance: Actors, Challenges and Policy Recommendations*, <https://www.idos-research.de/en/briefing-paper/article/green-finance-actors-challenges-and-policy-recommendations/#:~:text=However%2C%20mobilising%20capital%20for%20green,the%20definition%20of%20%E2%80%9Cgreen%E2%80%9D>. [102]
- BIS (2021), <https://www.bis.org/bcbs/basel3.htm?m=3%7C14%7C572>. [60]
- BIS (2015), *Combining micro and macro data for financial stability analysis - Overview of the IFC Workshop, Warsaw, 14–15 December 2015*, Bank for International Settlements (BIS), https://www.bis.org/ifc/publ/ifcb41_overview_rh.pdf. [119]
- BlackRock (2019), <https://www.blackrock.com/us/individual/insights/blackrock-investment-institute/physical-climate-risks>. [58]
- Blijlevens, S. and M. Wiersma (2022), “The data challenge makes climate risk a very interesting but very complex scope of work”, *Zanders Group*. [63]

- Bloomberg (2022), "Tesla plant opening hit by legal challenge over water", *Automotive News Europe*, <https://europe.autonews.com/automakers/tesla-plant-opening-hit-legal-challenge-over-water> (accessed on 6 January 2023). [32]
- BNM (2022), *An Exploration of Nature-Related Financial Risks in Malaysia*, <https://www.bnm.gov.my/documents/20124/3770663/wb-bnm-2022-report.pdf>. [110]
- CDP (2023), *Riding the Wave How the private sector is seizing opportunities to accelerate progress on water security*, <https://www.cdp.net/en/research/global-reports/global-water-report-2022>. [29]
- CDP (2023), *Water*, <https://www.cdp.net/en/water>. [79]
- CDP (2022), *Disclosing through CDP - The business benefits*, https://cdn.cdp.net/cdp-production/comfy/cms/files/files/000/006/049/original/CDP_Benefits_of_Disclosure_brochure_2022.pdf. [78]
- CDP (2022), *High and Dry: How Water Issues Are Stranding Assets -A report commissioned by the Swiss Federal Office for the Environment (FOEN)*, CDP, London, <https://www.cdp.net/en/research/global-reports/high-and-dry-how-water-issues-are-stranding-assets> (accessed on 6 January 2023). [13]
- CDP (2021), *A wave of change: The role of companies in building a water-secure world*, Global Water Report 2020, <https://www.cdp.net/en/research/global-reports/global-water-report-2020> (accessed on 11 January 2023). [30]
- CERES (2022), *The Global Assessment of Private Sector Impacts on Water*, CERES, Saskatchewan. [24]
- Ceres (2023), *Investor Water Toolkit*, Investor Toolkits, <https://www.ceres.org/resources/toolkits/investor-water-toolkit/details#understand-water-risks> (accessed on 12 January 2023). [112]
- Ceres (2023), *Valuing Water Finance Initiative*, <https://www.ceres.org/water/valuing-water-finance-initiative#:~:text=The%20Valuing%20Water%20Finance%20Initiative,to%20better%20protect%20water%20systems>. [81]
- Ceres (2021), *Financial Implications of Addressing Water-Related Externalities in the Apparel Sector*, Ceres, <https://www.ceres.org/resources/reports/financial-implications-addressing-water-related-externalities-apparel-sector> (accessed on 27 January 2023). [100]
- Ceres (2021), *Financial Implications of Addressing Water-Related Externalities in the Meat Sector*, CERES, Boston, <https://www.ceres.org/resources/reports/financial-implications-addressing-water-related-externalities-meat-sector> (accessed on 27 January 2023). [101]
- Ceres (2018), *Investor Water Toolkit A Project of Ceres Investor Water Risk*, Ceres, Boston. [114]
- CISL (2022), *HSBC water stress - heavy industry credit risk*, https://www.cisl.cam.ac.uk/files/cisl_hsbc_water_stress_heavy_industry_credit_risk_apr_22.pdf. [118]
- CISL (2021), *Handbook for nature-related financial risks*. [33]

- CISL and HSBC (2022), *Nature-related financial risk: use case. Impact of water curtailment on credit rating of heavy industry companies in East Asia*, University of Cambridge Institute for Sustainability Leadership (CISL) and HSBC. [49]
- Colin, S. et al. (2018), *Mapping Public Water Management by Harmonizing and Sharing Corporate Water Risk Information*, <https://www.wri.org/research/mapping-public-water>. [5]
- Coloia, F. and D. Jansen (2021), *Flood risk and financial stability: Evidence from a stress test for the Netherlands*, De Nederlandsche Bank, Amsterdam, <https://www.dnb.nl/en/publications/research-publications/working-paper-2021/730-flood-risk-and-financial-stability-evidence-from-a-stress-test-for-the-netherlands/> (accessed on 20 December 2022). [7]
- Consilium Europa (2022), *Council gives final green light to corporate sustainability reporting directive - Consilium*, The European Council Press release, <https://www.consilium.europa.eu/en/press/press-releases/2022/11/28/council-gives-final-green-light-to-corporate-sustainability-reporting-directive/> (accessed on 9 January 2023). [72]
- DNB (2020), *Indebted to nature: Exploring biodiversity risks for the Dutch financial sector*, <https://www.dnb.nl/media/4c3fgawd/indebted-to-nature.pdf>. [111]
- DoL (2022), *Final Rule on Prudence and Loyalty in Selecting Plan Investments and Exercising Shareholder Rights*, Department of Labour (DoL), <https://www.dol.gov/agencies/ebsa/about-ebsa/our-activities/resource-center/fact-sheets/final-rule-on-prudence-and-loyalty-in-selecting-plan-investments-and-exercising-shareholder-rights>. [70]
- DoL, U. (2021), <https://www.dol.gov/newsroom/releases/ebsa/ebsa20210310>. [69]
- ECB (2022), *2022 climate risk stress*, European Central Bank, https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.climate_stress_test_report.20220708-2e3cc0999f.en.pdf. [8]
- ECB (2022), *Walking the talk – Banks gearing up to manage risks from climate change and environmental degradation - Results of the 2022 thematic review on climate-related and environmental risks*, European Central Bank, Frankfurt, <https://doi.org/10.2866/417808>. [48]
- ECB (2021), *Climate-related risk and financial stability*, European Central Bank, Frankfurt, <https://doi.org/10.2866/913118>. [31]
- ECB (2021), https://www.bankingsupervision.europa.eu/press/publications/newsletter/2021/html/ssm.nl210818_5.en.html. [47]
- ECB (2021), <https://www.ecb.europa.eu/pub/pdf/other/ecb.climateriskfinancialstability202107-87822fae81.en.pdf>. [62]
- ECB (2020), *Guide on climate-related and environmental risks - Supervisory expectations relating to risk management and disclosure*, <https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.202011finalguideonclimate-relatedandenvironmentalrisks-58213f6564.en.pdf>. [35]

- ECB (2020), *Guide on climate-related and environmental risks Supervisory expectations relating to risk management and disclosure*, European Central Bank, Frankfurt, <https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.202011finalguideonclimate-relatedandenvironmentalrisks~58213f6564.en.pdf> (accessed on 6 January 2023). [28]
- EcoLab (2022), *Smart Water Navigator - Achieve Water Targets and Water Resilience*, ECOLAB, <https://en-fr.ecolab.com/corporate-responsibility/environment/water-stewardship/smart-water-navigator> (accessed on 12 January 2023). [113]
- EIOPA (2022), *Discussion paper on physical climate change risks*, European Insurance and Occupational Pensions Authority, https://www.eiopa.europa.eu/document-library/discussion-paper/discussion-paper-physical-climate-change-risks_en (accessed on 11 January 2023). [66]
- EIOPA (2022), *Solvency II: Leading the way in managing sustainability risk | Eiopa*, European Insurance and Occupational Pensions Authority, https://www.eiopa.europa.eu/media/speeches-presentations/contribution/solvency-ii-leading-way-managing-sustainability-risk_en (accessed on 11 January 2023). [67]
- EIOPA (2021), *REPORT on non-life underwriting and pricing in light of climate change*, European Insurance and Occupational Pensions Authority (EIOPA), Frankfurt. [51]
- European Commission (2023), *Annex I: Sustainable use and protection of water and marine resources*, https://finance.ec.europa.eu/system/files/2023-06/taxonomy-regulation-delegated-act-2022-environmental-annex-1_en_0.pdf. [104]
- European Commission (2023), *Overview of sustainable finance*, https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en. [88]
- FSB (2022), *Climate Scenario Analysis by Jurisdictions - Initial findings and lessons*, Financial Stability Board (FSB), <https://www.fsb.org/wp-content/uploads/P151122.pdf>. [85]
- Government of Netherlands (2023), *Valuing Water Initiative*, <https://valuingwaterinitiative.org/about-us/>. [80]
- GRI (2022), *The materiality madness: why definitions matter*, Global Report Initiative (GRI), Amsterdam, <https://www.globalreporting.org/media/r2oojx53/gri-perspective-the-materiality-madness.pdf> (accessed on 6 January 2023). [25]
- Haraguchi, M. and U. Lall (2015), *Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making*, International Journal of Disaster Risk Reduction. Volume 14, Part 3., <https://doi.org/10.1016/j.ijdrr.2014.09.005>. [18]
- Hernandez, A. (2023), *French environment minister urges restrictions to avoid water crisis*, <https://www.reuters.com/world/europe/french-environment-minister-urges-quick-restrictions-avoid-water-crisis-2023-03-06/>. [17]
- IFAC (2015), *Materiality in <IR> Guidance for the preparation of integrated reports*, The International Federation of Accountants (IFAC), New York, <https://www.ifac.org/knowledge-gateway/preparing-future-ready-professionals/publications/materiality-integrated-reporting> (accessed on 5 January 2023). [22]
- III (2022), *Stemming a rising tide - how insurers can close the flood protection gap*, Insurance Information Institute (III), https://www.iii.org/sites/default/files/docs/pdf/flood-report_triple-i_capgemini_sept-2022.pdf. [54]

- IMF (2020), *Global Financial Stability Report: Markets in the Time of COVID-19*, International Monetary Fund, Washington, <https://www.imf.org/en/Publications/GFSR/Issues/2020/04/14/global-financial-stability-report-april-2020#Chapter5> (accessed on 10 January 2023). [56]
- IPBES (2019), *Summary for policymakers of the global assessment report on biodiversity and ecosystem services*, <https://zenodo.org/record/3553579>. [1]
- IPCC (2023), *AR6 Synthesis Report: Climate Change 2023*, <https://www.ipcc.ch/report/sixth-assessment-report-cycle/>. [10]
- IPCC (2023), *Press release: AR6 Synthesis Report*, <https://www.ipcc.ch/2023/03/20/press-release-ar6-synthesis-report/>. [21]
- IPCC (2022), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Summary for Policymakers*, <https://www.ipcc.ch/report/ar6/wg2/>. [2]
- IUCN (2021), *Corporate disclosures related nature lagging far behind climate*, <https://www.iucn.org/news/climate-change/202111/corporate-disclosures-related-nature-lagging-far-behind-climate>. [77]
- IUCN (2021), *Peatlands and climate change*, <https://www.iucn.org/resources/issues-brief/peatlands-and-climate-change>. [34]
- Jones, H. and S. Jessop (2021), *Companies' climate disclosures still lacking -task force*, Reuters, <https://www.reuters.com/business/sustainable-business/companies-climate-disclosures-still-lacking-task-force-2021-10-14/> (accessed on 11 January 2023). [74]
- Jonsdottir, B. et al. (2022), "Barriers to Using ESG Data for Investment Decisions", *Sustainability* 2022, Vol. 14, Page 5157, Vol. 14/9, p. 5157, <https://doi.org/10.3390/SU14095157>. [91]
- Jubels, R. (2022), "Get ready for European Sustainability Reporting Standards - KPMG Global", KPMG, <https://home.kpmg/xx/en/home/insights/2022/05/european-sustainability-reporting-standards-eu-esrs.html> (accessed on 6 January 2023). [73]
- Lee, Y. (2021), *Chipmakers in drought-hit Taiwan order water trucks to prepare for 'the worst'*, Reuters, <https://www.reuters.com/business/autos-transportation/chipmakers-drought-hit-taiwan-order-water-trucks-prepare-the-worst-2021-02-24/>. [19]
- Mazzucato, M. et al. (2023), *Turning the Tide: A Call to Collective Action*, <https://watercommission.org/publication/turning-the-tide-a-call-to-collective-action/>. [3]
- Mohanty, A. and S. Wadhawan (2021), *Mapping India's Climate Vulnerability: A District-Level Assessment*, Council on Energy Environment and Water (CEEW), New Delhi. [38]
- MunichRe (2020), <https://www.munichre.com/en/risks/natural-disasters-losses-are-trending-upwards/floods-and-flash-floods-underestimated-natural-hazards.html>. [44]
- Mytton, D. (2021), "Data centre water consumption", *npj Clean Water* 2021 4:1, Vol. 4/1, pp. 1-6, <https://doi.org/10.1038/s41545-021-00101-w>. [41]
- Naik, G. (2021), *Water stress is the main medium-term climate risk for Europe's biggest economies*, S&P GLOBAL, <https://www.spglobal.com/esg/insights/water-stress-is-the-main-medium-term-climate-risk-for-europe-s-biggest-economies> (accessed on 21 December 2022). [42]

- Naik, G. (2021), *Water stress is the main medium-term climate risk for Europe's biggest economies* | S&P Global, S&P GLOBAL, <https://www.spglobal.com/esg/insights/water-stress-is-the-main-medium-term-climate-risk-for-europe-s-biggest-economies> (accessed on 11 January 2023). [52]
- NASA (2021), *Brazil Battered by Drought*, NASA Earth Observatory. [40]
- NBIM (2021), <https://www.nbim.no/en/publications/submissions-to-ministry/2020/climate-risk-in-the-government-pension-fund-global/>. [98]
- NCEI (2022), *Billion-Dollar Weather and Climate Disasters*, NOAA National Centers for Environmental Information (NCEI), <https://www.ncei.noaa.gov/access/billions/>, (accessed on 21 December 2022). [43]
- NCFA (2018), *Exploring Natural Capital Opportunities, Risks and Exposure: A practical guide for financial institutions*, Natural Capital Finance Alliance and UN Environment World, https://www.unepfi.org/wordpress/wp-content/uploads/2018/11/NCFA_Exploring-Natural-Capital-Opportunities-Risks-and-Exposure_Nov-2018.pdf. [108]
- NGFS (2022), *Credit Ratings and Climate - Challenges for Central Bank Operations*, https://www.ngfs.net/sites/default/files/medias/documents/credit_ratings_and_climate_change_-_challenges_for_central_bank_operations.pdf. [93]
- NGFS (2022), *NGFS acknowledges that nature-related risks could have significant macroeconomic and financial implications* | Banque de France, Network for Greening the Financial Sphere Press release, <https://www.ngfs.net/en/communique-de-presse/ngfs-acknowledges-nature-related-risks-could-have-significant-macroeconomic-and-financial> (accessed on 9 January 2023). [86]
- NGFS (2022), *Statement on Nature-Related Financial Risks*, https://www.ngfs.net/sites/default/files/medias/documents/statement_on_nature_related_financial_risks_-_final.pdf. [37]
- NGFS (2021), *Guide on climate-related disclosure for central banks*, https://www.ngfs.net/sites/default/files/medias/documents/guide_on_climate-related_disclosure_for_central_banks.pdf. [61]
- NGFS (2021), *NGFS publishes the second vintage of climate scenarios for forward looking climate risks assessment*, Network for Greening the Financial Sector, <https://www.ngfs.net/node/368148>. (accessed on 21 December 2022). [84]
- NGFS (2020), *Guide to climate scenario analysis for central banks and supervisors*, https://www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_scenario_analysis_final.pdf. [83]
- Noels, J. and R. Jachnik (2022), *Assessing the climate consistency of finance: Taking stock of methodologies and their links to climate mitigation policy objectives*, <https://doi.org/10.17>. [92]
- OECD (2023), *Private finance mobilised by official development finance*, OECD Publishing, Paris, <https://www.oecd.org/dac/2023-private-finance-odfi.pdf>. [87]
- OECD (2022), *ESG ratings and climate transition*, OECD Publishing, <https://doi.org/10.1787/2fa21143-en>. [90]

- OECD (2021), *Climate risks to the financial system manifesting through water: Understanding financial materiality*, Background Paper for Round Table on financing water 8th Roundtable on Financing Water: Thematic meeting focused on Climate Action 23-24 September 2021, <https://www.oecd.org/water/Background-paper-RT-on-Financing-Water-and-Climate-Action-Session-3.pdf> (accessed on 21 December 2022). [6]
- OECD (2020), *Developing Sustainable Finance Definitions and Taxonomies. Green Finance and Investment*, <https://doi.org/10.1787/134a2dbe-en>. [103]
- OECD (2020), *ESG Investing: Environmental Pillar Scoring and Reporting*, OECD Publishing, <https://www.oecd.org/finance/ESG-Investing-Environmental-Pillar-Scoring-and-Reporting.pdf>. [27]
- OECD (2020), *Policy Guidance on the Structure of Insurance Regulation and Supervision*, OECD Publishing, <https://www.oecd.org/daf/fin/insurance/Policy-Guidance-on-the-Structure-of-Insurance-Regulation-and-Supervision.pdf>. [59]
- Painter, M. (2020), “An inconvenient cost: The effects of climate change on municipal bonds”, *Journal of Financial Economics*, Vol. 135/2, pp. 468-482, <https://doi.org/10.1016/J.JFINECO.2019.06.006>. [57]
- Penning-Rowsell, E. and S. Priest (2015), *Sharing the burden of increasing flood risk: who pays for flood insurance and flood risk management in the United Kingdom. Mitig Adapt Strateg Glob Change* 20, 991–1009, <https://doi.org/10.1007/s11027-014-9622-z>. [64]
- PIDE (2022), *Water Crisis in Pakistan: Manifestation, Causes and the Way Forward*, Pakistan Institute of Development Economics (PIDE), Islamabad, <https://pide.org.pk/wp-content/uploads/kb-060-water-crisis-in-pakistan-manifestation-causes-and-the-way-forward.pdf> (accessed on 27 January 2023). [39]
- Press, C. (ed.) (2013), *Climate Change 2013 – The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Intergovernmental Panel on Climate Change, <https://doi.org/10.1017/CBO9781107415324>. [107]
- PRI (2022), *Inevitable Policy Response*, Principles for Responsible Investment, <https://www.unpri.org/sustainability-issues/climate-change/inevitable-policy-response> (accessed on 9 January 2023). [106]
- Ramsar (2019), *Wetlands: the key to coping with climate change*, https://www.ramsar.org/sites/default/files/documents/library/wwd19_handout_e.pdf. [12]
- RE, F. (2023), *How Flood Re works*, <https://www.floodre.co.uk/how-flood-re-works/>. [53]
- Ridley, M. and D. Bolan (2016), *Integrating Water Stress in Corporate Bond Analysis*, German Federal Ministry for Economic Cooperation and Development (BMZ), <https://vf.u.de/water-risk-tool/>. [94]
- S&P (2023), *Climate Credit Analytics*, <https://www.spglobal.com/marketintelligence/en/solutions/climate-credit-analytics>. [95]
- SASB (2020), <https://www.sasb.org/blog/double-and-dynamic-understanding-the-changing-perspectives-on-materiality/>. [36]

- SBTN (2023), *Technical Guidance 2023 - Freshwater*, [116]
<https://sciencebasedtargetsnetwork.org/wp-content/uploads/2023/05/Technical-Guidance-2023-Step3-Freshwater-v1.pdf>.
- SBTN (2023), *The first science-based targets for nature*, Science Based Targets Network, [115]
<https://eur02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.ipbes.net%2Fevents%2Fipbes-ipcc-co-sponsored-workshop-biodiversity-and-climate-change&data=05%7C01%7CLylah.DAVIES%40oecd.org%7C470cff24c4da4f7da35808db4d607fa5%7Cac41c7d41f61460db0f4fc9>.
- SEC (2022), *SEC Proposes Rules to Enhance and Standardize Climate-Related Disclosures for Investors*, US Securities and Exchange Commission - Press Release, [68]
<https://www.sec.gov/news/press-release/2022-46> (accessed on 27 January 2023).
- Shamsudduha, M. and R. Taylor (2020), *Groundwater storage dynamics in the world's large aquifer systems from GRACE: uncertainty and role of extreme precipitation. Volume 11, issue 3*, <https://doi.org/10.5194/esd-11-755-2020>. [16]
- Shi, X. et al. (2019), *Changes in Major Global River Discharges Directed into the Ocean*, [15]
<https://doi.org/10.3390/ijerph16081469>.
- SwissRE (2022), *Natural catastrophes in 2021: the floodgates are open*, [45]
<https://www.swissre.com/institute/research/sigma-research/sigma-2022-01.html#:~:text=In%202021%2C%20there%20were%20more,are%20becoming%20ever%20more%20apparent>.
- SwissRE (2021), <https://www.swissre.com/dam/jcr:16271084-77b5-478f-b6ce-8948f94cba4e/sigma-1-2021-secondary-perils-en.pdf>. [50]
- TCFD (2017), *Recommendations of the Task Force on Climate-related Financial Disclosures*, Task Force on Climate-related Financial Disclosures, <https://www.fsb-tcfd.org/recommendations/#:~:text=The%20TCFD%20recommendations%20on%20climate,included%20in%20mainstream%20financial%20filings>. (accessed on 20 December 2022). [82]
- TNFD (2023), *The TNFD Nature-related Risk and Opportunity Management and Disclosure Framework - Final Draft – Beta v0.4*, https://framework.tnfd.global/wp-content/uploads/2023/03/23-23882-TNFD_v0.4_Integrated_Framework_v7.pdf. [75]
- TNFD (2022), *Discussion paper: A Landscape Assessment of Nature-related Data and Analytics Availability*, https://tnfd.global/wp-content/uploads/2022/03/TNFD_DataDiscussionPaper.pdf. [99]
- TPT (2022), *Consultation - The Transition Plan Taskforce Disclosure Framework*, [71]
<https://transitiontaskforce.net/wp-content/uploads/2022/11/TPT-Disclosure-Framework.pdf>.
- UN (2020), *Climate Action Pathway, Water, Executive Summary*. [4]
- UNCTAD (2022), *Chapter 4 – Capital Markets and Sustainable Finance*, World Investment Report 2022, <https://worldinvestmentreport.unctad.org/world-investment-report-2022/chapter-4-capital-markets-and-sustainable-finance/> (accessed on 10 January 2023). [55]
- UNEP (2023), *Addressing water-related conflict and disasters*, <https://www.unep.org/explore-topics/water/what-we-do/addressing-water-related-conflict-and-disasters#:~:text=Most%20of%20the%20impacts%20of,impact%20on%20societies%20and%20economies>. [11]

- UNESCO (2022), *The United Nations World Water Development Report 2022: groundwater: making the invisible visible*, <https://unesdoc.unesco.org/ark:/48223/pf0000380721.locale=en>. [9]
- Valuing Water Initiative (2021), *The Valuing Water Initiative announces partnership with CDP, Mercer and the Water Footprint Network to accelerate water-related transparency and action for the financial sector - Valuing Water Initiative*, <https://valuingwaterinitiative.org/news/new-partnership-announcement/> (accessed on 12 January 2023). [76]
- WEF (2021), *Global Risks Report 2021*, World Economic Forum, <https://www.weforum.org/reports/the-global-risks-report-2021/> (accessed on 11 January 2023). [97]
- WEF (2020), *What is green finance and why is it important?*, <https://www.weforum.org/agenda/2020/11/what-is-green-finance/>. [89]
- World Economic Forum (2020), *Half of the world's GDP is moderately or highly dependent on nature*, <https://www.weforum.org/press/2020/01/half-of-world-s-gdp-moderately-or-highly-dependent-on-nature-says-new-report/>. [20]
- Wurtsbaugh, W., C. Miller and S. Null (2017), *Decline of the world's saline lakes*, *Nature Geosci* 10, 816–821, <https://doi.org/10.1038/ngeo3052>. [14]
- WWF (2020), *New Water Risk Filter Scenarios will help companies and investors turn risk into resilience*, World Wide Fund For Nature - News, https://wwf.panda.org/wwf_news/?933366/New-Water-Risk-Filter-Scenarios-will-help-companies-and-investors-turn-risk-into-resilience. [105]
- WWF (2019), *Linking water risk and financial value - PART I - Considerations for the financial sector*, https://wwfint.awsassets.panda.org/downloads/wwf_waterrisk_financialvalue_part1_web.pdf. [23]