Risk ownership for transboundary climate risks in global supply chains

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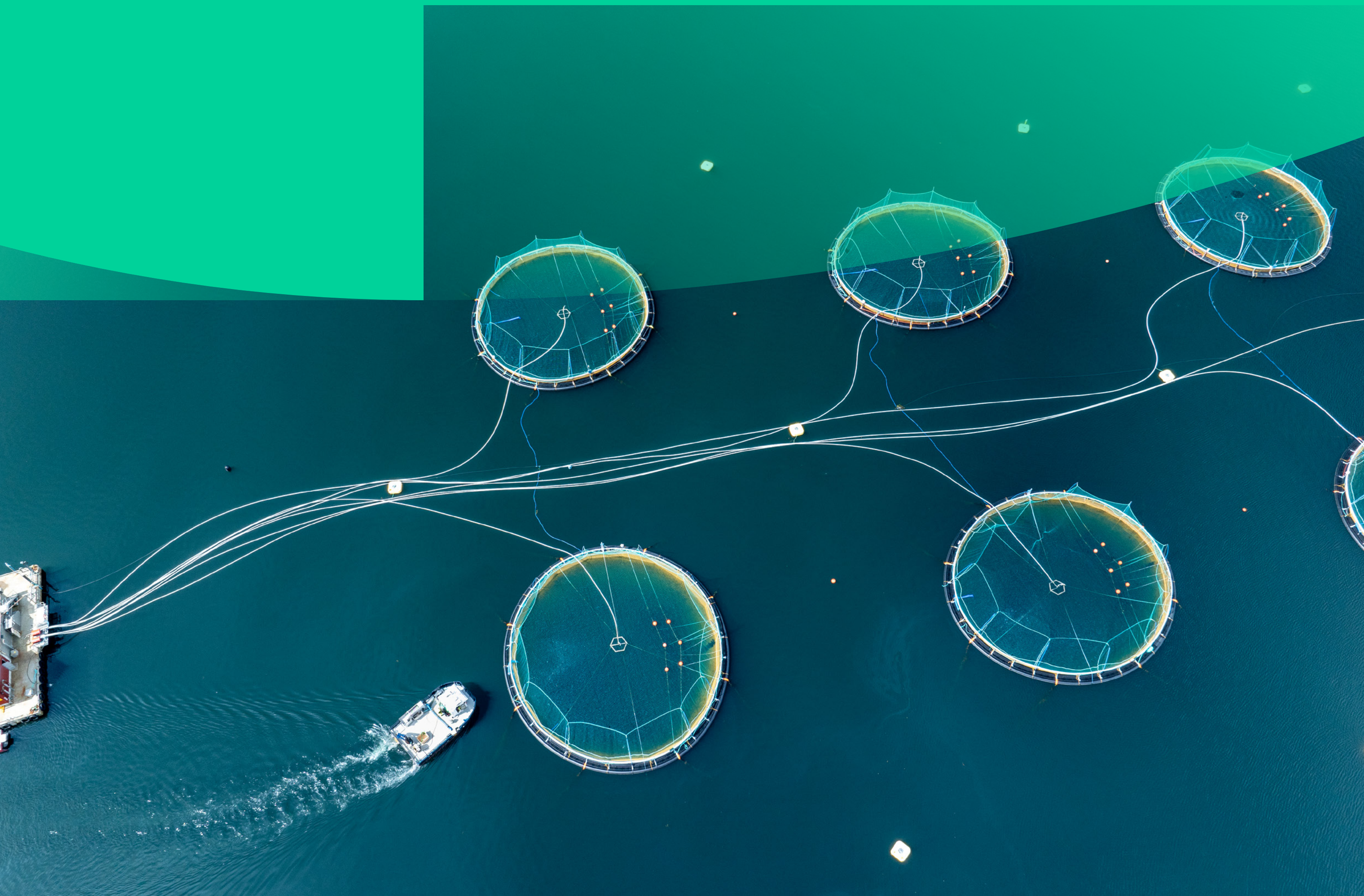

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Contents

Abstract

Transboundary climate risks pose complex challenges, propagating across borders and sectors and affecting global supply chains, economies and governance systems. However, the ownership of these risks remains unclear, making adaptation efforts fragmented and less effective. This paper introduces a framework to map risk ownership in global supply chains, helping identify key stakeholders, assets and objectives at risk. By applying this framework to the case of Brazilian-produced soy products imported for fish food in Norway, we illustrate how climate risks – and the adaptation measures to address them – extend beyond direct supply chain actors to industries, governments and broader economic systems. The framework highlights the systemic nature of transboundary climate risks, emphasizing the need for coordinated, cross-sectoral approaches to adaptation. It also raises critical questions on fairness and responsibility, as differing risk exposures and incentives influence who takes action. Ultimately, the framework provides a foundation for improving risk governance and enhancing climate resilience in interconnected global systems.

1. Introduction

The transboundary nature of climate risks has been increasingly recognized, along with the need for international cooperation to address them (Harris et al., 2024). Transboundary climate risks are likely to generate impacts that propagate across borders (Carter et al., 2021) and can affect diverse interconnected elements in a global economy, including people, trade, finance and infrastructure (Benzie et al., 2019). Impacts arising from transboundary climate risks can be transmitted and propagated across different scales, including neighbouring and remote regions, and can be experienced in the same region where a climate event occurs or in a different one (Carter et al., 2021). Both physical climate risks and risks arising from the adaptation measures to overcome such risks can be transboundary (Adaptation Without Borders, 2017).

These transboundary climate risks can impact global supply chains through various risk pathways, in isolation or in concert, causing shocks and disruptions in the supply of goods and services. For example, physical risks arising from heat waves or storms can limit not only the manufacturing but the mobility of goods (Amiot et al., 2023). Whereas many large companies have moderately diversified supply chains, which are more resilient to shocks, expectations are that more frequent and severe climate-related physical risks will likely require further adaptation efforts (Amiot et al., 2023). Moreover, global supply chains will intensify economic losses from heat-related risks by extending or propagating indirect impacts to broader areas beyond national boundaries (Sun et al., 2024).

Countries and subnational areas may have different risk exposure and capacities to manage different risk scales, depending on how their economies participate in global supply chains. Risks and losses can spread across different geographical locations, and the location of physical assets is an unreliable indicator of the location of the potential financial loss (Semieniuk et al., 2022). Risk propagation depends on the stakeholders involved, and it matters which types of owners are holding the risk, as they may have their own potential to transmit it (Semieniuk et al., 2022). In a global supply chain, the production location of goods traded might not be the only risk location, and importers and final consumer locations may have larger risks than previously imagined.

The interconnection and interdependence of transboundary climate risks across borders and scales will require a coordinated approach to adaptation (Craft & Fisher, 2018; New et al., 2022), as it requires the co-generation of solutions by different stakeholders (Ringsmuth et al., 2022). Therefore, there is a need to understand who, how and where those risks will be managed (Bednar-Friedl et al., 2022). In the business management sector, risk management is done by a “risk owner”, a person or entity with the authority and capacity to manage and respond to a risk (ISO, 2021).

The concept of risk ownership also has been recently used to understand responsibility and accountability for climate-related responses, including in disaster risk reduction to forest fires (Young & Jones, 2018), as well as for financial and transition risks of oil and gas stranded assets (Semieniuk et al., 2022). In the case of transboundary climate risks, there is limited knowledge of how these risks arise and propagate, making the allocation of risk ownership challenging.

The complex and systemic nature of transboundary climate risks makes clarifying risk ownership a key step to identifying adaptation options (Harris et al., 2022), and it is expected to increase the efficacy and impact of the risk management response, while helping to identify how such a response is financed (Surminski et al., 2022). However, unlike with single hazards, risk ownership in transboundary climate risks is not straightforward and has rarely been analysed in climate risk governance assessments (Hedlund, 2023). Therefore, clarity on ownership of transboundary climate risks is not yet determined (Aall et al., 2023; Harris et al., 2022; Hedlund, 2023), and stakeholders (who experiences the risk(s)?) and values and objectives (what is at risk?) need to be explored.

In this working paper, we present a framework for helping understand risk ownership and risk propagation of transboundary climate risks through global supply chains, particularly to identify where there is limited or unclear risk ownership. We reviewed business management and transboundary climate risk literature to understand better the concept of risk ownership, and based on this review, we present a five-step framework aimed at exploring stakeholders and values and objectives at risk. We apply the framework to analyse the case of zero-deforestation non-GMO soy protein concentrate imports in Norway, which presents characteristics of a simple cross-border climate impact transmission system.

By identifying stakeholders, values and objectives at risk, the framework can help governments, businesses and other stakeholders to understand the interdependencies and systemic nature of climate risks, particularly within a global supply chain. The framework showcases how different sectors in different locations across borders are affected by both climate risks and the solutions proposed to manage them. It also sharpens the picture for very specific actors, beyond simple broad categories.

2. Managing transboundary climate risks in global supply chains

Global supply chains are primarily led by businesses and financial institutions, with governments' interventions playing a less dominant role. The assumption by governments, businesses and banks is that free trade and liberal market practices put businesses and banks in the best position to manage risks (Cote & Mikaelsson, 2023).

Some major businesses are making the effort to track their climate risks. In 2023, 100 major businesses reported that climate risks affected 10% of their annual sales and 4% of their market value (WEF & PWC, 2023).

However, another survey shows that less than a third (27%) of businesses have a good understanding of the climate risks affecting their supply chains (Gartner, 2022). And another source found that only one in five companies have planned adaptation measures (Laidlaw et al., 2023). This limited understanding of climate risks within global value chains leads to reduced awareness of the importance of such risks within business operations, even when operations cross multiple tiers of supply networks (Cote & Mikaelsson, 2023). Other barriers for adaptation from businesses include short time frames for risk management and lack of incentives within the current political landscape (Mikaelsson & Davis, 2024).

The role of governments in promoting adaptation within global value chains could therefore include incentives for businesses to adapt to climate change through legal or policy requirements (Cote & Mikaelsson, 2023). Such incentives should avoid exacerbating vulnerabilities, particularly for those members of society who are already most vulnerable, such as people living in poverty or who are members of marginalized groups (Mikaelsson & Davis, 2024; Ringsmuth et al., 2022). This highlights the need for a coordinated approach, for businesses to act with governments, to minimize the effects of supply chain disruptions and shocks of key products and their cascading effects in society (Cote & Mikaelsson, 2023).

Managing transboundary climate risks may require risk management to allocate responsibility for complex and systemic risks, including finding ways to share such responsibility among diverse stakeholders working together despite uncertainties (Ringsmuth et al., 2022). This reorganization would be particularly relevant for global supply chains, dealing with complex and interconnected supply systems and risks. In adapting to climate change, risk ownership is crucial for effective risk management, as it helps to understand who should be responsible and where (Young et al., 2017; Young & Jones, 2018).

Clearly defining risk ownership can help minimize potential losses, improve the effectiveness and impact of the response, and clarify how that response will be funded (Clarke & Dercon, 2016; Surminski et al., 2022). Without a risk owner, it is likely that transboundary climate risks will get no such oversight and therefore will not be managed (Harris et al., 2022).

Research on disaster risk insurance also shows that risk ownership alone is not enough. Even in cases where mandates exist at local and national scales to deal with a (disaster) risk, and where such a mandate is used as a way to allocate risk ownership, if the risk ownership is limited or unclear, and incentives are lacking to act in advance, the result can be an inappropriate preparedness and response (Surminski et al., 2022).

3. Risk ownership in transboundary climate risks

Assigning ownership for transboundary climate risks is complex (Hedlund, 2023). Complexity arises from the fact that even when the transboundary nature of climate risks is recognized, ownership of such risks is rarely explicitly assigned in adaptation policy documents (Harris et al., 2022).

However, the concept of risk ownership in the context of business management implies that the ownership of risks is assigned (by management), according to capacities (see Box 1, page 9 for a discussion of this expectation). This “assignment” is not necessarily done for transboundary climate risks in global supply chains. In part this is because the networks of actors involved belong to different levels of governance (e.g. subnational, national, supranational), each with different levels of information and mandates (Aall et al., 2023). Stakeholders can become risk owners if (a) there is a mandate or responsibility to manage a risk or (b) there is interest in the public good or from a humanitarian perspective. At the same time, action requires incentives to motivate such networks (e.g. government, market actors, civil society) to co-generate solutions. Selecting the right incentives or motivations is challenging, as network actors have different objectives and values at risk (Ringsmuth et al., 2022).

In addition, addressing transboundary climate risks requires an additional level of coordination across international borders (Bednar-Friedl et al., 2022). This global governance scope is often outside the mandates of local and national governments, and ownership of such risks can be perceived as “nobody’s job” (Anisimov et al., 2023). Therefore, these risks need innovative governance approaches, frameworks for risk ownership, and cooperation mechanisms across different scales (Anisimov & Magnan, 2023).

These characteristics highlight the negotiated and political nature of the allocation of risk ownership for addressing transboundary climate risks, where power dynamics are important (Harris et al., 2022). This is particularly relevant for food trade systems, which include private and public risk management strategies with different objectives (Benzie, 2023), as well as other similar sectors, such as pharmaceuticals (Cervest, 2022).

Box 1. What is risk ownership? A summary from the business management literature

Published research on business management usually works with the definition of a risk owner as “a person or an entity with the *accountability* and *authority* to manage risk” (ISO, 2021, p. 20). Therefore risk ownership is used to understand who is responsible for the actions to mitigate, transfer, accept or avoid a risk (Jahn et al., 2018). This definition implies that risk ownership must be explicitly assigned, authority for managing the risk is awarded, and a risk owner is appointed (by management) for every particular risk (Årstad & Engen, 2018; Caron, 2013; Lester, 2021). Identifying and assigning risk ownership could therefore prevent major disruptions (Årstad & Engen, 2018), and it has been linked to operational sustainability (Luburić, 2017). However, risk ownership is dynamic: it can change abruptly as a result of risk contagion and when capacity thresholds are crossed (Young & Jones, 2016).

Risk owners can be selected from a pool of stakeholders potentially affected by projected risks, from communities, businesses and the public sector, depending on the context of the risk (Young & Jones, 2016). At the same time, risk is contextual to individuals, communities or countries (Cuthbertson et al., 2019; Freire et al., 2021). Each stakeholder may understand different portions of a risk or have different uncertainties; some risks might be more relevant for some than others (Cagno & Micheli, 2011; Heravi et al., 2022; Ülkü et al., 2007). This multiplicity of actors means that risk ownership may not be the responsibility of a single actor, but shared within an interactive network of owners at different levels, from local to national (Årstad & Engen, 2018). Different actors will have different levels of responsibility and different roles in managing the risk, depending on the severity of the risk and the capacities of different actors (Freire et al., 2021; Raikes et al., 2022).

In this context of multiple actors, collaboration is required to manage the risk effectively (Farnsworth et al., 2016; Young & Jones, 2016), though challenging, as a multiplicity of stakeholders will result in different formal and informal values at risk (Allender et al., 2017). Negotiation is more critical when there is a lack of clarity on who is responsible (Krausmann & Necci, 2021), or when there are trade-offs between different actors (Young & Jones, 2018).

Allocation of risk ownership can use different instruments, including policies, legislation, regulation, strategies and plans, contracts and agreements, and social contracts (Young et al., 2017). Whereas regulations are expected to be used as a main instrument for allocating risk ownership, regulatory changes tend to be slow-paced compared to what is needed (Aven & Ylönen, 2016).

In addition to allocation, risk ownership needs to be acknowledged and accepted for risk management to be effective (Krausmann & Necci, 2021). As accepting risk ownership implies costs for the risk owner (Almarri et al., 2019), different incentives have been used to ensure uptake (Ülkü et al., 2007). In some cases, risk ownership may be unacknowledged until an event occurs, resulting in unprepared owners who may not be able to fulfil their ownership obligations (Young & Jones, 2018). Such acknowledgement requires communication and reporting mechanisms in place (Young, 2015). Finally, risk ownership can also be rejected or neglected.

4. Framework for identifying risk ownership for transboundary climate risks

Limited knowledge of how transboundary climate risks arise and propagate makes the allocation of risk ownership challenging. To fill this gap, we propose a five-step framework for policymakers and businesses to help identify stakeholders, risks and values at risk; aiming to understand where there is, and where there is not, clarity on risk ownership (Figure 1). This framework is based on a previously developed risk ownership framework (Young et al., 2017), adapted to a transboundary climate risks context by including the impact transmission concept framework for cross-border impacts of climate change (Aall et al., 2023; Carter et al., 2021; Menk et al., 2022). The steps in this framework are similar to and expand the research questions in the scoping stage of the protocol for case study research on transboundary climate risks (see Harris et al., 2022).

Figure 1. Framework for identifying risk ownership for transboundary climate risks

	STEP 1 Define system	STEP 2 Climate impact chain	STEP 3 Stakeholders and values	STEP 4 Climate responses	STEP 5 Map risk ownership
PRODUCER COUNTRY/IES	Farmer Aggregator Industry Exporter Transport infrastructure (rail, port)	Climate trigger (e.g. drought, flood) Reduced productivity	Ministry of agriculture Ministry of climate Ministry of environment Sustainability network	Ministry of finance	Risk owners will be selected from the stakeholders identified in *previous steps.* This step is also used to identify those cases where risk ownership is unclear, contested, or avoided.
INTERMEDIARY LOCATIONS	Transport Ports (first import) Certification scheme	Climate trigger (e.g. drought, flood)	Infrastructure authorities	Substitute producer(s) Other certification scheme	
IMPORTER COUNTRY/IES	Importer First consumer industry Second consumer industry	Higher prices Reduced competitiveness	Ministry of industry Ministry of climate Ministry of environment National authorities Sustainability network	Innovation authority Other industrial group	

Source: Authors' own

A desk-based case study is presented as an illustration of the framework in the boxes throughout, based on soy protein concentrate imported by the Norwegian aquaculture industry. This example is based on the ongoing work for transboundary climate risks for soy and maize in Norway, as part of the TRANSADAPT project. This is not an in-depth case study; therefore, diverse variables and actors might be missing.

Step 1. Define the system boundary: identify direct stakeholders trading a specific commodity

Defining a system boundary starts with selecting a traded good or commodity and mapping the key stakeholders, such as producers and consumers, based on trading data. This step aims to identify different stakeholders along the supply chain, from the initial country (i.e. producer country), through an impact transmission system, until the final recipient location (i.e. importer country) (Carter et al., 2021; Talebian et al., 2023). Further stakeholders are mapped in step 3.

Whereas the specific characteristics of the trade system under analysis may differ depending on the good or commodity traded, as well as the countries involved in the supply chain, it generally involves the same basic group of actors – producers and production sites, intermediaries (i.e. transport systems, and those involved in the transport of the commodity) and buyers. Attention has predominantly focused on producers and buyers, with less emphasis on the intermediaries/transport links between them; however, climate risks associated with the transportation component itself within international value chains are critically important to understanding their systemic nature (Aall et al., 2022).

See the example in Box 2 for an illustration based on soy protein concentrate imported to Norway from Brazil as fish food for the farmed salmon industry.

Box 2. System boundary for soy protein concentrate imported from Brazil to Norway

The specific commodity in this case study is genetically unmodified (non-GMO) soy protein concentrate, a soybean product that is important for the salmon feed industry in Norway. In this simple case, Brazil is the producer country and Norway is the importer country, getting almost all (90%) of its soy protein concentrate imported from Brazil (EY, 2019).

Non-GMO soy represents only about 2–3% of the total soy production in Brazil, but it is essential for producing the soy protein concentrate required for the Norwegian aquaculture industry. Non-GMO soy protein concentrate produced in Brazil is certified by ProTerra Standard, a certification by the ProTerra Foundation, that also includes requirements on respecting human rights, good labour and agricultural practices, and avoiding deforestation (ProTerra Foundation, 2019). All the non-GMO soy protein concentrate imported by Norway is certified by ProTerra (Aas et al., 2022).

Only three Brazilian companies export non-GMO soy protein concentrate to the Norwegian salmon feed industry: Caramuru, CJ Selecta (a part of Bunge since 2024), and Imcopa/Cervejaria Petrópolis (ProTerra Foundation, 2022). Caramuru and CJ Selecta do not have their own plantations and instead work directly with soy farmers in three states: Mato Grosso, Minas Gerais and Goiás. These companies have traceability systems in their supply chains, allowing buyers to identify from where the soy beans are sourced, to comply with certification by ProTerra.

▶

The intermediate spaces include the exporter groups and key infrastructure managers who are typically in charge of transporting commodities (see Box 2 Table 1). There are no specific data for soy protein concentrate. For this exercise, data on soybeans exported from Brazil directly to Norway are used as a proxy commodity, indicating that Amaggi (42%), Denofa do Brasil (12%) and Bunge (9%) were the main companies involved in the transport of this commodity in 2020 (SEI & Global Canopy, 2023).

Key ports for exporting soy protein concentrate in Brazil are Santana (the state of Amapá), and Santos (the state of São Paulo). Caramuru has an active lease for one of the terminals in the Port of Santana. Non-GMO soy protein concentrate exported to Norway usually goes through Port of Brake in Germany.

In this case, the main importers of zero-deforestation non-GMO soy protein concentrate are the Norwegian-based operations of major international fish feed manufacturers (Zhang & Chen, 2021), including four large companies: Skretting AS, Cargill (formerly EWOS), BioMar AS and Mowi Feed AS (Aas et al., 2022). Skretting and Cargill consume together about 75% of the soy protein concentrate imported to Norway in 2016 (Lundeberg & Leifsdatter Grønlund, 2017).

The consumer of fish feed in Norway is the aquaculture industry, in particular for farmed salmon (i.e. Grieg Seafood, Leroy Seafood, Cermaq, Norway Royal Salmon and Mowi), which is export-oriented. In this example, we focus on the boundaries of trade involving the input source (Brazil) and the industries within Norway, although it could potentially extend to a broader range of salmon-importing customers.

Box 2 Table 1. System boundary for soy protein concentrate from Brazil imported by Norway

Producer country: Brazil	Intermediate spaces	Importer country: Norway
Soy producers' areas: states of Mato Grosso, Minas Gerais and Goiás Non-GMO soy protein concentrate producers: • Caramuru • CJ Selecta • Imcopa/Cervejaria Petrópolis Key ports and transport infrastructure (e.g. "chokepoints"): • Port of Santana (Amapá) • Port of Santos (São Paulo)	Exporter groups (data for soybeans as a proxy to soy protein concentrate): • Amaggi • Denofa do Brasil • Bunge Countries of first import: • Germany (Port of Brake)	Importer group: No information on importer (logistics) found Direct importer industry (fish feed industry): • Skretting • Cargill Aqua Nutrition • BioMar • Mowi Feed Consumers from direct importer industries (farmed salmon industry): • Grieg Seafood • Leroy Seafood • Cermaq • Norway Royal Salmon • Mowi

Step 2: Define the transboundary climate impacts

For this step, we suggest using the cross-border impacts conceptual framework (Carter et al., 2021). To start, it is important to define a time frame for the climate risks (e.g. by 2030 or 2050). This step will highlight the cross-border or transboundary impacts arising from a climate event and may highlight values at risk, including assets (e.g. infrastructure damaged by a mudslide) and objectives at risk (e.g. increase in production volume). Clarifying transboundary impacts will also help to identify the location(s) of a risk along the supply chain and the type of transmission of the risk. Other variables, including how to assess the risk, should also be considered, though they are beyond the scope of this paper.

Depending on the location of the impacts (e.g. single or multiple locations) and the presence or absence of feedback loops, the transmission should be classified as simple, spatially complex, dynamically complex, or systemic (Talebian et al., 2023) (see Table 1). Higher spatial and dynamic complexity of impacts across regions makes it more difficult to identify risk ownership. An impact transmission for the example of soy protein concentrate would be a drought in Brazil, with knock-on effects in Norway for fish farming, across a direct line of three industries; this illustrates a simple cross-border climate impact type (see Box 3).

Table 1. Cross-border climate impacts typology

Spatial complexity

Spatially complex Climate impact in one country transmits to another country through system components in multiple locations (in remote regions or in multiple regions). The dynamic of transmission is a single-tier cascade, with direct links between producers, processors and consumers.	**Systemic** Climate impact in one country is transmitted through multiple system components in multiple regions. The transmission dynamics could be through multiple system components, can originate in multiple locations and can generate feedback.
Simple Climate impact in one country transmits to another country (neighbouring or remote regions) in a single-tier cascade from one system component (e.g. stakeholder or value) to the other.	**Dynamically complex** Climate impact in one country cascades through multiple system components and can originate in multiple locations before affecting another country or can generate feedback between multiple system components.

Dynamic complexity

Source: Adapted from Talebian et al. (2023)

Box 3. Climate impact transmission for Brazilian zero-deforestation non-GMO soy protein concentrate imports to Norway

Non-GMO soy protein concentrate production areas are located mainly in Mato Grosso, Minas Gerais and Goiás, which are part of the Cerrado biome, a biodiversity hotspot in Brazil. Climate change is expected to lengthen drought periods in the Cerrado between 1% and 6% for every 1°C of temperature increase in the area (Silva et al., 2023). Depending on the climate model used, the rainfed area in the Cerrado with ideal soybean production conditions will be halved by 2030 (Rattis et al., 2021). Other studies however, predict a yield increase of soy in all climatic zones in Brazil (Figueiredo Moura Da Silva et al., 2021). These discrepancies are common when using climate predictions, so decisions should be made on which assumptions are used to identify future climate impacts and risks.

The cross-border climate impact transmission of non-GMO soy protein concentrate from Brazil to Norway can be classified as a simple impact type (see Table 1 in the main text). The spatial complexity is low, as the main source of soy protein concentrate is located in a single country, Brazil. In addition, the commodity is supplied by only three companies in Brazil, and only one industry – the fish feed industry – is the main consumer, while another single industry is the ultimate consumer of the feed produced, for farmed salmon. In addition, we found only one intermediate place, the Port of Brake in Germany, that is impacted in the trade chain.

The climate impact transmission starts from a climate trigger (drought in non-GMO soy growing areas) in Brazil, reducing yields of non-GMO soy, which then reduces supply for soy protein concentrate production targeting Europe and Norway (see Figure Box 3.1). This would likely increase the input price for fish feed production in Norway, resulting in higher fish feed prices for farmed salmon, which would then lead to higher salmon prices. As the farmed salmon production in Norway is mostly export-oriented, this could affect the competitiveness of farmed salmon compared to producers in other countries (e.g. Chile, Scotland).

Whereas no specific climate impact transmission was identified in the intermediary location (Germany) in this example, intermediary places can be important in the transmission system. Including them in the analysis remains key.

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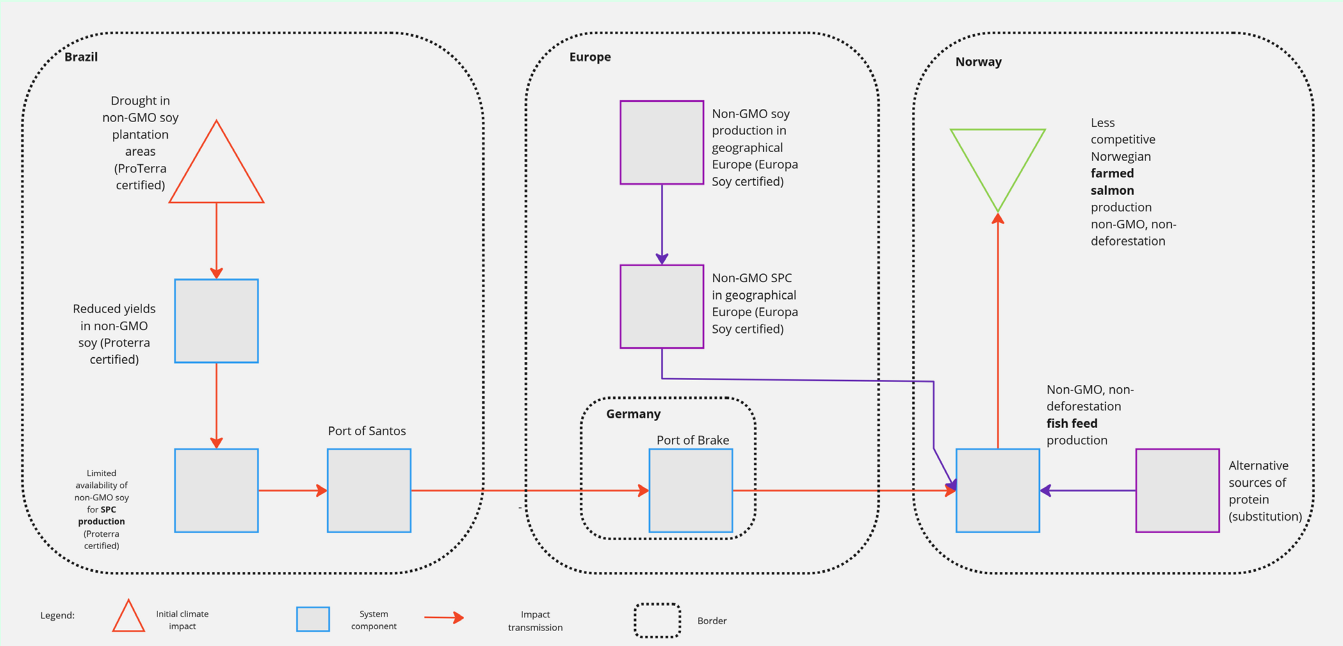
Figure Box 3.1. Initial impact transmission of droughts in Brazil affecting the fish feed and salmon industry in Norway



Source: Authors' own

Step 3. Identify additional stakeholders and values at risk

Beyond identifying the direct stakeholders (step 1), it is important to identify additional stakeholders and their values that might be at risk within the supply chain (step 3). Additional stakeholders include actors in the public and private sectors. They may work at different scales (e.g. transnational, national, local). Actors could own or manage assets (e.g. a port) or have objectives (e.g. fivefold increase in the local farmed salmon industry by 2050) that may be at risk under a cross-border climate impact transmission system.

This step is useful for identifying coherence between climate risks and involved industries' objectives (see Kivimaa et al., 2024). This step helps framework users determine whether climate triggers and their cross-border impacts pose a risk to achieving industrial or sectoral economic, social or environmental objectives. These at-risk objectives may include environmental sustainability, climate resilience, industrial safety and financial stability.

Beyond the actors identified in step 1 that are involved in commodity supply security, additional stakeholders include a mix of private and public organizations, such as industrial associations and sectoral public institutions (e.g. ministries and regulators). These entities may have specific objectives that could be directly or indirectly impacted by transboundary climate risks. The soy protein concentrate example on which we focus here illustrates additional stakeholders in both Brazil and Norway (see Box 4), and the objectives that could be affected by a climate trigger (e.g. drought in Brazil's Cerrado region).

Box 4. Additional stakeholders and values at risk

Brazil is one of the three main soy protein concentrate producers in the world, together with the US and China (Volza Export Trade Data, 2024). All soy production in Brazil has reduced deforestation objectives, supported by diverse policy instruments, including a moratorium on growing soy in the Amazon, adopted in 2016. We found no objectives specific to non-GMO soy protein concentrate. In addition, non-GMO soy production is a small proportion (2–3%) of total soy production in Brazil (ProTerra Foundation, 2023).

The Brazilian suppliers of soy protein concentrate to Norway – CJ Selecta, Caramuru and Imcopa/Cervejaria Petrópolis – are part of the "Aquaculture Dialogue for Sustainable Soy Sourcing from Brazil" (referred to here as the Aquaculture Dialogue), a roundtable with the Norwegian feed companies Skretting, Cargill Aqua Nutrition, BioMar and Mowi, established in 2019 together with World Wide Fund for Nature (WWF) Brazil and ProTerra to ensure a deforestation and conversion-free soy value chain from Brazil. This commitment has been adopted by the majority of the global farmed salmon industry and by the whole of the European salmon sector (Mowi, 2021). Norway is highly dependent on Brazilian providers of soy and soy protein concentrate.

In Brazil, for the specific states sourcing soy, Mato Grosso has a "Produce, Conserve and Include" (PCI) plan, launched in 2015, which includes objectives to (1) increase productivity of soy agriculture, (2) expand agriculture in grassland degraded areas from 9.5 million to 12.5 million hectares by 2030, and (3) reduce deforestation by 90% by 2030 (State of Mato Grosso, 2021). Drought could hinder the PCI objective of increasing soy productivity unless targeted adaptation measures are planned and implemented. A decline in soy yields in Brazil may disrupt soy protein concentrate supply to Norway, given the significant reliance of the Norwegian fish feed industry on Brazilian soy protein concentrate.

Norway's farmed salmon industry is the largest in the world and represents about 70% of the country's seafood export value (Norwegian Seafood Council, 2025). Feed represents the largest share of the total cost in the farmed salmon industry, and Norway used about 46% of the global feed towards salmon in 2022 (Mowi, 2023b). This share showcases the increased importance of vegetable materials in the feed of Norwegian salmon farming, which shifted from 11% in 1990 to 70% in 2022 (Mowi, 2023b). One of the Norwegian aquaculture industry's main goals is to grow fivefold by 2030 (Sjømat Norge, 2014), which may require fish feed production to grow at the same scale, unless other alternatives are in place.

The fish feed industry in Norway has required non-GMO and zero-deforestation soy since 2004. Norwegian fish feed growth could be constrained by potential disruptions in the supply of non-GMO and zero-deforestation Brazilian soy protein concentrate, which may also threaten Norway's aquaculture growth objectives.

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In Norway, the aquaculture industry is regulated by the Directory of Fisheries, part of the Ministry of Trade, Industry and Fisheries, following the national Aquaculture Act. Regulation is meant to “promote the profitability and competitiveness of the aquaculture industry within the framework of a sustainable development and contribute to the creation of value on the coast” (Nærings- og fiskeridepartementet, 2005).

This step of the framework (step 3) makes it clearer how the objective of competitiveness of the Norwegian aquaculture industry could be impacted by reduced availability of non-GMO, zero-deforestation soy from Brazil. See Table Box 4.1 for additional stakeholders identified in this step.

Table Box 4.1. Additional stakeholders in Brazil and Norway and their objectives that could be potentially impacted by drought in Brazil

Typology of actors	Organization	Example of type of objectives
Producer country: Brazil		
Public local	Mato Grosso state	Produce, Conserve and Include (PCI) plan, with the objective to increase productivity of soy agriculture
Intermediate/other spaces		
Transnational actors	Aquaculture Dialogue for Sustainable Soy Sourcing from Brazil	Ensure a deforestation and conversion-free soy value chain from Brazil in Europe
Importer country: Norway		
Public national	Directorate of Fisheries (Aquaculture management) within the Ministry of Trade, Industry and Fisheries	Profitability and competitiveness of the aquaculture industry within the framework of sustainable development
Private national	Sjømat Norge	Fivefold growth in salmon production by 2050

Note: More actors need to be added depending on the complexity of the impact chain.

Source: Authors’ own

Step 4. Identify existing climate adaptation responses

Identifying the already planned adaptation responses and how these will propagate or be transmitted throughout the global supply chain is also crucial to mapping already clear risk ownership. Responses to climate risks are usually set out in climate adaptation policy documents (e.g. policies, legislation, regulation) and within industries' planning documents (e.g. standards, strategies, plans, assessments, and contracts and agreements) (Young et al., 2017). Adaptation responses are expected to indicate responsible institutions or individuals, from which risk owners can be identified.

Responsibility for climate adaptation responses will vary depending on the location of the intervention (Talebian et al., 2023), the governance level (e.g. global, transnational, international, domestic) (Dzebo & Adams, 2023), and the funding source (Dzebo & Adams, 2023). They can also vary depending on the economic model preferred in the location where the response is to be implemented (e.g. market economies, command economies).

In this step of the framework, the objective is to acknowledge that a climate adaptation response also can alter the impact of a climate risk. This can be done by reducing the impact through (a) absorbing the risk (i.e. absorbing higher costs), (b) substituting the commodity, (c) transferring the risk through financial mechanisms, or (c) changing the objectives at risk (e.g. reducing profit) (Talebian et al., 2023). Planned responses may include identifying alternative options in case a response proves ineffective.

Box 5. Climate responses in Brazilian soy protein concentrate imported by Norwegian fish feed industry

In step 4 for the soy protein concentrate case study, the impact transmission is complemented with the response transmission. Other geographic locations are added to the transnational setting, and related actors can be identified based on the responses. In this case, the main response strategy is to develop alternative sources of protein in Norway and source soy from Europe. So far, alternative sources and soy from Europe represent a very small portion of the soy protein concentrate used by the fish feed industry in Norway.

Responses identified in the desk review are mainly domestic in Norway, aiming to substitute the Brazilian soy protein concentrate for EU-produced and EU-certified soy protein concentrate; and by investing in alternative protein sources. EU-produced soy protein concentrate is available from companies that are members of Donau Soja, a nonprofit organization that supports non-GMO soy producers in Europe. The organization's members pledge that their soy will not lead to deforestation and conversion of land to agriculture from other uses, while complying with non-GMO EU regulations (Donau Soja, 2024). Large fish feed companies, such as Skretting and BioMar, have started to include soy protein concentrate produced in Europe since 2020.

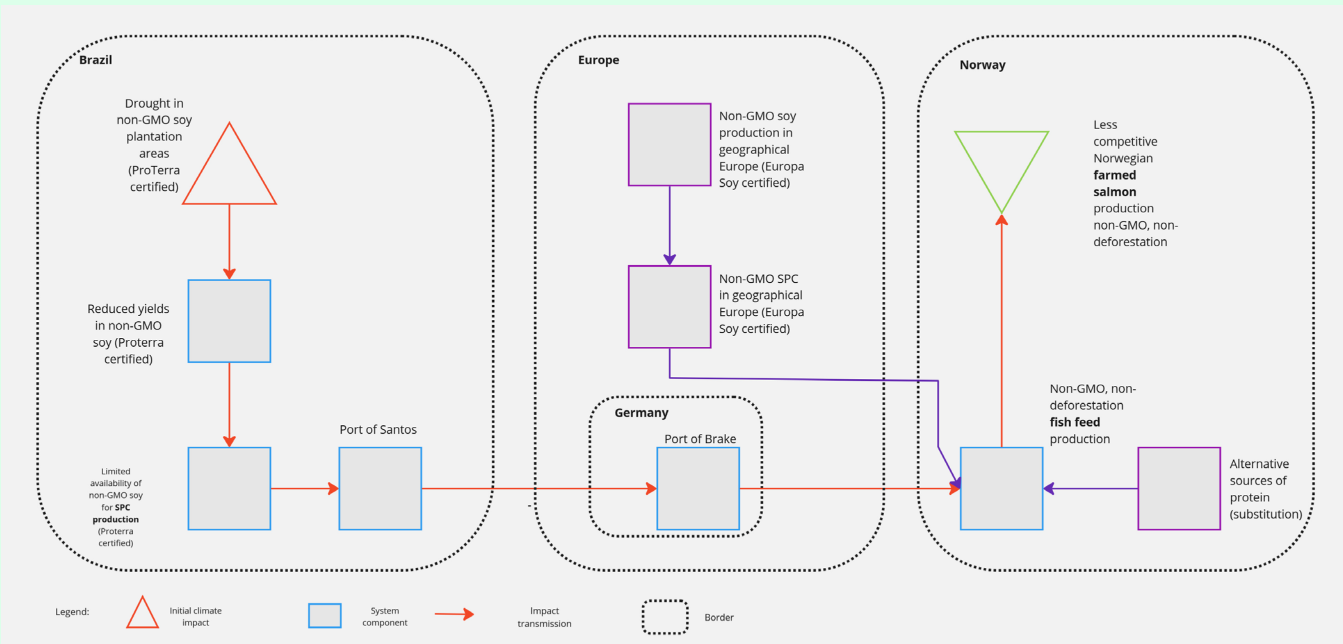
Alternative protein sources include insects, bacteria, yeast and micro-algae (Moren, 2021), but they are not currently produced on the volumes required by the salmon industry (Howell, 2022). Skretting has been developing alternative protein sources to replace soy and fish meal, including insect meal (black soldier fly larvae) since 2018 (Skretting, n.d.). Mowi included 2.5% of alternative protein sources in 2022 (e.g. pea protein concentrate) and aims to achieve 10–15% from these and other emerging feed raw materials by 2030 (Mowi, 2023a).

Government-funded research in Norway also supports the development of alternatives protein sources to soy. For example, Nofima, the Norwegian food research institute, together with the University of Bergen and the Norwegian technological research centre (NORCE), have managed the Aquafeed Technology Centre since 2021, with the objective of creating new raw materials for replacing soy in the country's aquaculture industry (Moren, 2021).

These responses also add stakeholders and objectives in our framework (see Figure Box 5.1). We highlight the importance of non-national funders as well, such as the EU Horizon 2020, which support innovation in the development of alternatives to soy protein.

From the producer country perspective, Brazil, no major responses were identified. However, it is important to note that some of the responses in Norway and Europe might also generate transboundary risks in Brazil: these include reduced demand for non-GMO and zero-deforestation soy protein concentrate.

Figure Box 5.1. Impact and response transmission of droughts in Brazil affecting the fish feed and salmon industry in Norway



Source: Authors' own

Step 5. Risk ownership mapping

In this last step of the framework, the objective is to identify risk ownership along the system – in this case a simple global supply chain where there are stakeholders with values at risk, capacities and incentives to own the risk (see Box 6). Risk owners can be identified from the stakeholders outlined in previous steps. If capacities or incentives are insufficient for stakeholders to accept risk ownership, a negotiation process might be needed. When assessing stakeholders' capacities to manage risk, a user of the framework should also consider risk scale, incentives in place and decision-making power, among other capacities (Table 2). These considerations include who receives support for addressing a risk, how the decision-making process is conducted (Siders, 2022), what risks and trade-offs are acceptable, and what priority is given to different adaptation measures (Byskov et al., 2021).

Table 2. Considerations for the negotiation process for risk ownership

Guiding questions for negotiating risk ownership	Description
Does the owner of the impacted value (an asset, an objective) have capacities to manage the risk?	Capacities include those for decision-making, affordability of the financial costs, and technical capacities to implement adaptation measures.
What are the incentives in place?	Risk ownership requires incentives and accountability (i.e. monitoring and evaluation) frameworks. Risk owners might also need to identify what might help them to have agency to intervene (Årstad & Engen, 2018).

Box 6. Risk ownership in Brazilian soy protein concentrate to fish feed industry

Risk owners by mandate are mostly public organizations dealing with adaptation or mitigation to climate change within producer or importer countries; however, companies (both producers and importers of a commodity) are also risk owners by mandate, depending on their own objectives of growth and sustainability. Risk owners by interest are those involved in the businesses affected by potential interruptions of the supply chain.

In the case of soy protein concentrate, in addition to public organizations, risk owners by mandate are the fish feed companies, which are dependent on the commodity. The risk owners by interest in this case are members of the Aquaculture Dialogue.

▶

Risk ownership is clear for specific goals within countries (e.g. responsibility for adaptation within Brazil, or within Norway). But it is unclear to what extent there is a responsibility from Norway to support adaptation within Brazil, even when Norway's fish feed and aquaculture industries have high dependence on Brazil's soy protein concentrate. In this case, it is unclear to what extent Norway is willing to support (technically or financially) the adaptation in Brazil, beyond the participation of Norwegian companies in the Aquaculture Dialogue.

Following our framework, the process also raised the issue of policy and industrial coherence. In this case, Sjømat Norge has a growth objective that might not be coherent with sustainability objectives within the farmed salmon industry in Norway, including the reduction in dependencies on Brazilian soy protein concentrate, considering potential shortages due to climate change.

5. Discussion and conclusion

In this working paper, we set out a framework to support the mapping of climate risk ownership in global supply chains, contributing to understanding climate risks more systematically through five steps. This process is crucial for more effective decisions on adaptation to transboundary climate risks.

This framework could prove to be particularly useful for the identification of stakeholders beyond those involved directly in the supply chain (e.g. producers in country A, importers in country B, in step 1), to include those stakeholders whose values (assets and objectives) might be at risk (e.g. industry guilds in country B, or ministries in country A and B). The framework therefore helps users to understand adaptation to climate risks beyond individual companies that produce and purchase a commodity, recognizing the systemic nature of climate risks.

However, even after walking through all five steps of this framework, the result may not be a clear map of risk owners. Instead, the result may be a map of stakeholders and values at risk, which may be the starting point for the negotiation process for determining the risk owners within a specific supply chain.

The application of this framework may start from the perspective of one interested party. However, with every step, the framework allows for mapping climate risks, stakeholders and objectives along a global supply chain, beyond the borders of the initial interested party.

In our example, we started the exercise from the perspective of Norwegian dependency on soy imports. However, the framework allowed us to explore in a limited way the potential climate impacts in Brazil, which raised questions of who should be responsible for ensuring non-GMO soy is available for Norwegian industries, as well as to what extent current objectives at risk (e.g. fivefold increase of aquaculture industry in Norway by 2050) need to be changed to make the whole supply chain more resilient and sustainable.

In addition to the understanding of the supply chain, this framework also requires information on climate impacts in all the locations involved. In particular, we recommend having specific climate impacts in specific subnational areas especially if the production is spatially concentrated (Stokeld et al., 2020). Climate risks to critical infrastructure, which in our case study included the ports of Brazil and the Port of Brake in Germany, should also be identified, as these risks can also disrupt the supply chain and are generally not included in the analysis of risks. However, even in the absence of such information, the framework at least raises their importance and makes these intermediate spaces more visible – and therefore part of the risk ownership discussion.

Whereas stakeholders are relatively easy to identify for both producer and importer countries, finding objectives specific for a commodity under analysis depends on the importance of the crop or raw material in each location. In our example, there were specific mandates for imported soy protein concentrate in Norway, but we didn't find particular objectives in Brazil for non-GMO soy or soy protein concentrate specifically. This may imply that this is significantly more important for Norway than for Brazil, and therefore there should be more incentives in Norway than in Brazil to plan for responses to climate changes and transmission of risks. It is also important to highlight that the example used in this paper is a simple supply chain system and that the more complexity in the supply chain, the more stakeholders and values there will be to consider. Application of this framework in more complex supply chains may reveal its limitations.

Finally, this framework does not reflect on the fairness of the distribution of transboundary climate risks ownership. Are capacities and incentives the main drivers? Who has the responsibility to support the de facto owners? And who decides what is fair? These questions also require discussion, especially considering the negotiated process of determining risk ownership.

Governments need to complement risk management practices and analyses on a business level with a broader sector-wide and economy-wide understanding of these risks. This framework is particularly important given that most national adaptation plans are usually coordinated by ministries responsible for the environment and typically developed on a sectoral basis – even though adaptation and climate risks cause impacts across different policy portfolios. This creates a challenge, as climate risks continue to be examined in silos, where interdependencies between sectors and the cascading impacts are not fully understood or assessed on a systemic level. This framework contributes to assessments of transboundary climate risks and plan responses based on a systemic approach, which is much needed to understand and manage climate risks interdependencies, especially in trade.

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Annex

Table A1. Stakeholders whose assets or objectives can be impacted by transboundary climate risks in a simple climate impact chain

Typology of actors	Producer country	Example of type of objectives
Producer country		
Public National	Ministry of producer activity (e.g. agriculture, fisheries, forestry)	Growth and sustainability levels of commodity production
	Ministry of foreign trade	Trade related objectives (e.g. position of country as market supplier)
	Ministry of environment/climate change	Land use change, deforestation, emissions
	Ministry of Finance	Tax-based revenues
Public local	Municipalities of production	Local production (e.g. jobs, income, production volumes)
Private National	Producers' associations/guilds	Sustainability Growth
	Main producers (i.e. specific companies)	Sustainability Growth
Private local	Main producer at the local level (specific companies)	Growth Sustainability
Importer country		
Transnational actors	Transport companies Regional regulations on the value chain (e.g. EU regulations) Global initiatives related to the commodity/value chain Insurers	Sustainability objectives Compliance with regulations objectives
Public National	Ministries of importer industries (e.g. industry, fisheries) National agencies regulating user industry (e.g. food safety authority, food security ministry) Ministry of foreign trade Ministry of environment/climate change	Growth and sustainability levels of commodity production Safety Trade objectives Climate change related objectives (adaptation, mitigation)
Public local	Municipalities of importing industries	Trade related objectives (e.g. position of country as market supplier)
Private National	Industries' associations/guilds Main importer companies	Sustainability of value chains
Private local	Main industrial user at local level (specific companies)	Sustainability objectives
Intermediate spaces (including transnational)		
Public	Port administrators Regional regulations on the value chain (e.g. EU regulations)	Adaptation to change Compliance with regulations
Private	Port administrators Transport companies Global initiatives related to the commodity/value chain Insurers	Climate change related objectives Sustainability of value chains objectives

Note: More actors need to be added depending on the complexity of the impact chain.

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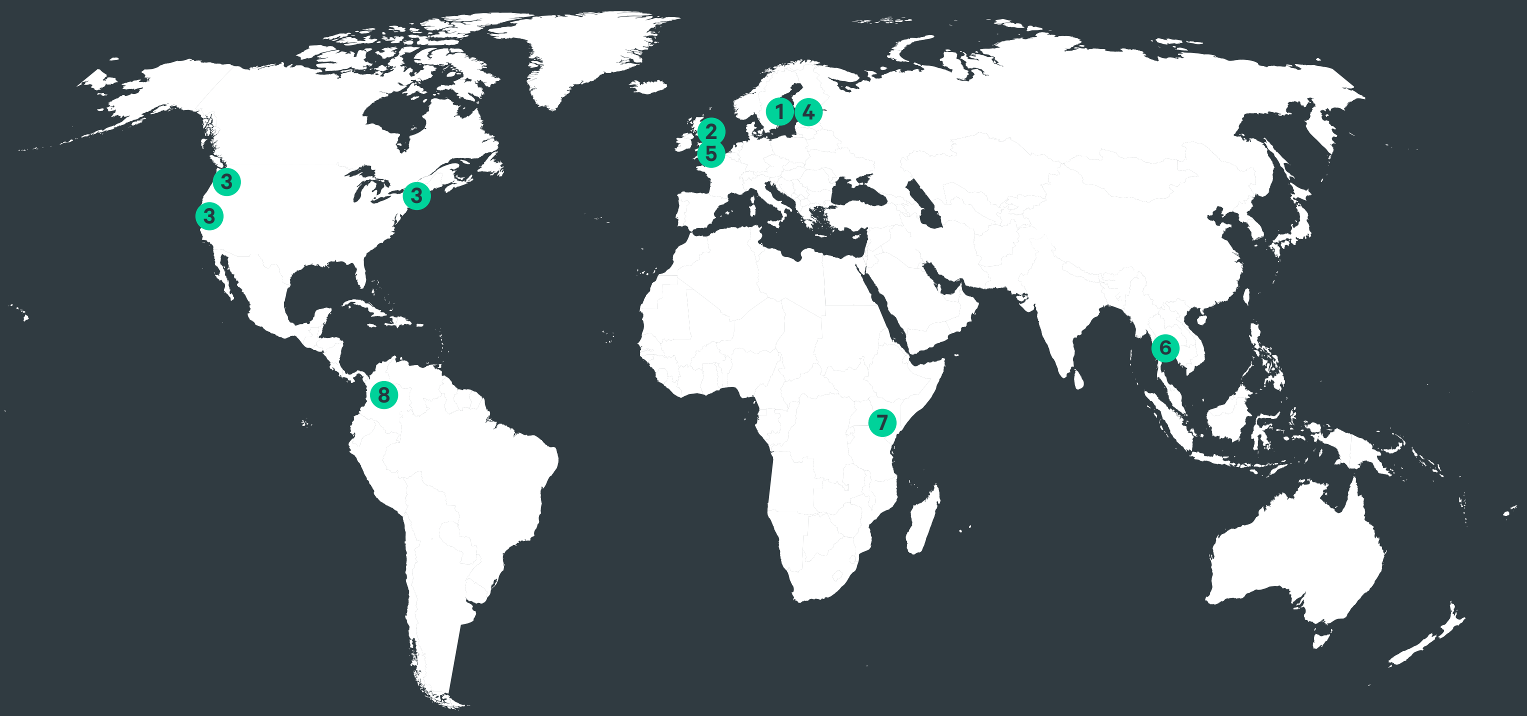

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