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Think global—act local: the challenge of producing actionable knowledge on transboundary climate risks at the sub-national level of governance

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A growing number of countries are putting transboundary climate risks on their national adaptation policy agenda. The designation of subnational governments as key actors in climate change adaptation policy appears to be appropriate when the risks associated with climate change are defined as "local." In this study we have investigated whether local authorities can plausibly play an equally central role when it comes to transboundary climate risks. Three cases have been studied: Paris in France and the topic of migration and integration, Klepp in Norway and the topic of agriculture and livestock production, and the river harbors in the Upper Rhine region of France and the topic of freight transportation and river regulation. Even if the sub-national actors involved in the three cases showed strong interest in analyzing and addressing transboundary climate risks, it remains an open question whether such authorities can and should play an equally central role in addressing transboundary climate risks as they do in the case of local climate risks. On the other hand, assigning responsibility for managing transboundary climate risks exclusively to national authorities may increase the risk of conflicts between measures to reduce local climate risks (frequently developed and implemented by sub-national authorities) and transboundary climate risks. The authors of this paper therefore advocate a strong partnership between the different levels of governance, and between public and private-sector stakeholders, in adaptation to transboundary climate risk. It is therefore crucial that national governments explicitly account for transboundary climate risks in their national adaptation agendas and, as part of their process in determining "ownership" of such risks, decide on the role sub-national authorities should play. This choice will also affect the role of local authorities in managing local climate risks due to the interlinkages between them.

KEYWORDS

climate impact chain, climate risk and vulnerability assessment, climate change, transboundary climate risk, local climate action

1. Introduction

Climate change risks are currently and primarily assessed from a territorial approach. Using the Intergovernmental Panel on Climate Change (IPCC) framework for analyzing climate risk (Reisinger et al., 2020), a territorial approach means that the assessment of hazards, exposure and vulnerability is limited to the same geographical area. However, we live in an interconnected world where the impacts of climate change are not confined by geographical borders—they can cross countries and continents, cascade across sectors, and disrupt and destabilize global systems. The transboundary nature of climate risk is increasingly acknowledged in adaptation settings, such as the 2021 EU Adaptation Strategy (EU, 2021) which repeatedly cites the importance of considering cascading impacts, but rarely is "ownership" of these risks explicitly assigned (Harris et al., 2022).

The designation of subnational governments as key actors in climate change adaptation policy appears to be appropriate when the risks associated with climate change are assessed from a "local" territorial approach and thus considering the diverse and context-specific responses that effective adaptation requires (Agder, 2001). However, in the case of transboundary climate risk, we are called to assess "to what extent there is a fit or mismatch between the problem scale and the governance scale" (Termeer and Dewulf, 2014). The interconnected nature of global systems, and transmission of climate risk through flows of trade, finance, natural resources, and movements of people, means that local actors are not always equipped with the global outlooks, information and mandates they would need to successfully adapt to these types of climate risk.

Still, recent studies in Norway, addressing representatives of subnational authorities, indicate that concern for this "new" type of "global" risk compared to the conventional "local" and territorially defined climate risk is increasing. In a survey sent out by the Norwegian Association of Local and Regional Authorities to all Norwegian municipalities, the share reporting that they expect to be "strongly" or "very strongly" affected by transboundary climate risks, explained as "climate change taking place in other parts of the world," increased from 15% in 2017 to 40% in 2021. The 2021 study ranked transboundary climate risks as number 3 of 7 predefined climate threats, and the category of climate threats with by far the largest percentage increase from 2017 to 2021 (Selseng et al., 2021). No similar studies are found from other countries (Selseng et al., 2021).

Given that local actors and jurisdictions in most countries are charged with the mandate to implement adaptation, and have an emerging awareness and understanding of the transboundary nature of climate risk, to what extent is it feasible for them to manage adaptation also to the transboundary climate risks they face? In this article we explore the management of transboundary climate risks at the sub-national level of governance, unlike the many other studies that have used the nation state as a reference point (Benzie et al., 2016; Hedlund et al., 2018; Benzie and Persson, 2019). Drawing on insights from three cases studies on attempts at local adaptation to transboundary climate risk (Norway, France, and Germany), we address the following research question: What are the problems and prospects for sub-national authorities to address transboundary climate risks?

2. What do we know about transboundary risks and how to address them?

Climate risks are usually viewed through a local lens, as the ways in which climate change impacts generate risk for a particular community or ecosystem depend on local conditions and societal characteristics (for example, whether a place is heavily settled or rural; the main sources of livelihoods; levels of wealth; the strength of local institutions and so forth). It is perhaps not surprising, therefore, that adaptation has traditionally been delegated to the local or national level to plan and implement. However, that leaves an important gap: how to handle climate risks that result from climate impacts in other jurisdictions. In this article, we call those transboundary climate risks. However, several other terms are also used in the academic and policy literature, such as transnational, cross-border, cascading, indirect and systemic, among others (Benzie et al., 2016).

Transboundary climate risks are risks that are being transmitted through various pathways from their physical point of origin (e.g., a drought or a flood) to one or more recipient regions. Carter et al. (2021) identifies seven pathways for the cross-border transmission of climate risks:

- Trade—the import and export of goods and services, as well as transport and processing sites.
- Finance—the flow of capital and other assets, such as foreign investment and remittances.
- People—tourism, pastoralism, migration or forced displacement.
- Psychological (also referred to as the "cognitive filter")—the perception and communication of climate risks and opportunities, especially as delivered by the media.
- Geopolitical—impacts on international relations, resource access, and foreign policy strategies of nations.
- Biophysical—shared ecosystems and resources, such as mountain ranges and river basins.
- Infrastructure—transport and telecommunications links.

One of the first national-level policy reports to specifically address transboundary climate risks was published in the United Kingdom in 2011 (Harris et al., 2022). Since then, transboundary risks have been mentioned in many national climate assessments, including of Canada, China, Finland, Germany, Kenya, Nauru, the Netherlands, Norway, Sweden, Switzerland, and the United States (Benzie and Persson, 2019). Some National Adaptation Plans and Nationally Determined Contributions (NDCs) have also referenced specific transboundary climate risks to particular sectors (Harris et al., 2022): indeed, the United States government has discussed a particular type of transboundary climate risks—international climate risks in the context of national security—since the 1980s (White House, 1987).

By their very definition, transboundary climate risks involve two or more jurisdictions: a country that experiences the initial climate hazard and a country (or more than one country) that experiences the resulting risk (Carter et al., 2021). Sub-national actors—such as local authorities, municipalities, and other forms

of devolved governments—are rarely equipped with the mandates or capabilities to fully manage risks that arise from outside their jurisdictions (Young and Jones, 2016; Harris et al., 2022). While it may be within their remits to mitigate or manage the resulting risk—creating food banks, for example, to diminish the effect of reduced availability of a critical food import because of a climate impact—they are unlikely to be able to directly influence either the "source" of the risk or factors along the chain(s) of impact, through the design of a new trade agreement, for example. This leaves them to act in a short-term "responsive" capacity rather than a long-term "preventative" capacity.

International relations are normally the domain of central governments at the national level (choreographed by finance, foreign policy or trade ministries for example), or regulated by international organizations, norms, and laws. This is certainly the case in the public sector, but it also applies to the private and social sectors with regards to capabilities and mandates at different scales This points to a mismatch of scale when assigning ownership (implicitly or explicitly) of transboundary climate risks to the sub-national level of governance. It is not only a question of mandate or authority. The relationships local actors tend to hold arguably do not often extend across an administrative border (to influence those who might be better positioned to pay for the risk, manage the risk, and are ultimately accountable for the risk) and they are less likely to be able to leverage others to act in these capacities (Young and Jones, 2016; Harris et al., 2022). There is also the question of administrative capacity to successfully implement measures to coordinate and manage the risk. Local actors tend to have more limited resources than national or international entities, and a more constrained operating environment within which to work. They are, essentially, small actors in a big world. This makes it harder for them to gain access to information, harder to mobilize resources (both financial and technical) to manage risks of a complex and dynamic nature, harder to hold enough sway to oversee the large-scale reforms that may be needed to prevent such risks from occurring, and harder to build in the redundancy and flexibility needed to cope with and respond to such risks when they do. Both their spheres of interest and influence are limited.

Still, sub-national actors can play an important role in setting an agenda in public debate and applying pressure on national and international entities to act. Such bottom-up or indirect actions from sub-national authorities are well-known in climate change mitigation. Front-runner municipalities, as well as national and international representatives of sub-national governments, have played an important role in advocating for ambitious GHG mitigation goals and the introduction of more effective national policy measures to support sub-national GHG-mitigation efforts (Aall et al., 2007).

Already in the first IPCC special report dealing with climate change adaptation, from 2012, the question of transformative strategies for adaptation is raised. The report presents the idea that some strategies for managing climate risks involve mere adjustments of current activities, whereas others require "transformative changes": "the altering of fundamental attributes of a system (including value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems)" (IPCC, 2012, p. 4). This should be compared to the definition of incremental adaptation (op. cit.), as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities."

The most recent IPCC contribution, the working group II report of the sixth assessment report (AR6) on impacts, adaptation, and vulnerability states that "in human systems, adaptation can be anticipatory or reactive, as well as incremental and/or transformational" (IPCC, 2022, p. 5). In the same report, the concept of transformation is linked to the concept of adaptation limits and the differentiation between hard and soft adaptation limits. While the notion of hard limits applies to a situation in which a system cannot be secured from intolerable risks through adaptive actions, soft limits imply that no concrete adaptation actions are currently available, but (radical) options may exist and (if so) need to be rapidly developed and implemented. Such alternatives will often be of a transformative as opposed to incremental nature (Dow et al., 2013). This insight is formulated in following way in the summary for policymakers: "Transitioning from incremental to transformational adaptation can help overcome soft adaptation limits" (IPCC, 2022, p. 27).

In this light, the limited capabilities of sub-national actors—under current conditions—to act effectively to mitigate or manage transboundary climate risks could be seen not as an absolute barrier but as a conditional "soft" limit or barrier. Therefore, overcoming such a barrier could arguably be achieved by transitioning from incremental to transformational adaptation.

3. Theoretical and analytical framework: what works where?

Climate change adaptation governance has aimed to be truly multi-level since and as a result of the adoption of the Paris Agreement on Climate Change in 2015 (Gonzales-Iwanciw et al., 2020). The Paris Agreement includes normative principles for the governance of adaptation, underpinning the necessity of both local and national environmental policy development to be under the strong influence of international agreements and policy instruments—a situation that has gained increasing momentum in the last couple of decades (Bulkeley, 2001; Andonova et al., 2009; Amundsen et al., 2010). The integration of adaptation into government (and governance) across levels and scales is considered critical to long-term climate resilience (Bulkeley, 2013). A crucial question then, in addressing various forms of climate risk, is what role is best suited to what level of governance, thus helping us to gain "an understanding of adaptation processes [that] allow interventions and planned adaptations at the most appropriate scales" (Agder, 2001, p. 1).

To guide our study, we have been inspired by an analytical framework used to evaluate a state-initiated major reform of local environmental policy in Norway (Naustadslid, 1994). The framework is related to the notion of governance levels and the idea that the characteristics of an environmental problem should determine which level of governance is most appropriate in dealing with the problem in question. The framework distinguishes between "concentrated" and "dispersed" environmental problems alongside two dimensions—"origin"

TABLE 1 A typology of environmental problems (adapted from Naustadslid, 1994).

		Cause	
		Concentrated	Dispersed
Impact	Concentrated	(1) Local problem, e.g., local pollution from a local factory	(2) Global-local problem, e.g., acid rain originating from several sources abroad causing fish death in Norwegian salmon rivers
	Dispersed	(3) Local-global, e.g., radioactive fallout from the Chernobyl nuclear power plant affecting large parts of Europe	(4) Global problem, e.g., the "climate problem" with a multitude of small and large emission sources causing global warming

and "manifestation"—of environmental problems. Based on this framework, Naustadslid (1994) formulated a hypothesis that local governments will primarily relate to environmental problems that can be characterized as of "concentrated" origin and manifestation—the true "local" environmental problems—unlike those that are "diffuse" in both origin and manifestation—the true "global" environmental problems. According to Naustadslid, the assessment of local environmental policy reform in Norway corroborated this hypothesis. Naustadslid (1994, p. 22) points out that "local governance bodies in the first place hardly can function as activators in the work with more superior, global environment problems... the municipalities give priority to issues which lead to visible local gains." Naustdalslid further comments that "if one wants the municipalities to give priority to global environmental issues, there is a need for national coordination of local environmental policy." He claims that "[such] an environmental-political U-turn presupposes changes in people's values and priorities" (Naustadslid, 1994, p. 25).

Aall (2012) has adapted Naustdalslid's framework of environmental problems to a climate context and points out that conventional climate change adaptation, addressing "local" climate risks, has more in common with the category "local" than "global" environmental problem, whereas the mitigation-focused climate policy clearly falls under the latter category. This division of the climate problem is reflected—in line with Naustdalslid's model—by the fact that adaptation is largely left to subnational actors, while mitigation is to a greater extent under the purview of national and international governance actors.

Applying the framework presented in Table 1 to the "new" form of climate risks—transboundary risks—we can identify three varieties of such risks:

- Category 2 "Global-local": for example, when various kinds of climate events in various countries affect import flows of climate-sensitive goods and services to one country, typically with a high degree of open economy.
- Category 3 "Local-global": for example, when climate events in one country lead to the emigration of climate refugees to different countries.
- Category 4 "global-global": for example, when climate hazards reduce the production of food in many countries at the same time and thus leads to a global increase in food prices and a subsequent reduction in global food security.

In-depth case studies of frontrunners indicate that municipalities *can* give priority to other forms of environmental problems than distinctly local ones *if* local actors are able to transform the "global" problem into a "local" one (Aall, 2000; Corell, 2003; Kates et al., 2003). The extensive activities under the Local Agenda 21 policy initiative through the 1990s illustrates this point (Lafferty and Eckerberg, 1998; Lafferty, 2001). To achieve this, there is a need to develop appropriate concepts and metaphors which bring out the connection between the local and the global (Hägerstrand, 1991) as well as addressing the challenges noted earlier regarding interest and influence, mandate, and capability. Given that these conditions are present, local authorities can be more capable than national authorities in the task of translating a global issue into a local context—thereby making the problem at stake comprehensible and relevant for policy action (Aall, 2000).

A tool which can prove useful in translating "from global to local" which has also gained increasing interest in climate research is the creation and use of boundary objects and the identification or creation of "boundary organizations." The latter is defined by Dannevig et al. (2019) as an organization that can straddle the two domains of science and policy due to its dual duty to both. Boundary organizations, with sufficient legitimacy, may create bridges between stakeholders that are not used to working together and facilitate the transfer of different kinds of knowledge (Callon et al., 2001; Gustafsson and Lidskog, 2017). They may also increase the usability of climate knowledge for adaptation action across a wider range of users (Kirchhoff et al., 2014).

Boundary organizations can make use of and will often focus on developing specific boundary objects. According to Leigh (2010), a boundary object is information which can be presented in various formats (maps, figures etc.), used in various ways, by various actors for the purpose of creating collaborative work across scales. Using boundary objects can lead to institutional conflicts as well as innovations (Zietsma and Lawrence, 2010). Thus, following Spee and Jarzabkowski (2009), referred to by Willems and Giezen (2022), boundary objects can be utilized as artifacts to either change, maintain, or disrupt institutions.

Francxo-Torres et al. (2020) point at the important role boundary objects can play in sustainability transitions. They illustrate this point by analyzing the Copenhagen municipality's transition to more sustainable stormwater management between 2007 and 2019, which was strongly affected by the most intense local cloudburst ever recorded on 2 July 2011. In this case, it was the mere work on climate change adaptation that served as a boundary object. The authors summarize three ways in which the actors used boundary objects (op.cit.): (1) to articulate a specific challenge (e.g., a climate risk), (2) to mobilize the necessary resources to address the challenge in question (e.g., an adaptation measure), and (3) to build cooperation across actors with conflicting interests. In this example, the boundary object utilized is a conceptual artifact.

An important enabling factor for new challenges to become a salient policy issue is the formation of boundary objects and boundary organizations. This has proven important for the case of

climate change adaptation (Dannevig et al., 2019), although so far (mostly, if not only) in the context of "local" climate risks. In this study, we look at the utilization of the Impact Chain framework as a boundary object and how effective it may be in relation to transboundary, and not just local, climate risk; and if so, what role it can play in putting transboundary climate risk on the local policy agenda. See Harris et al. (2022) for a justification of the use of the impact chain framework in the context of a transboundary climate risk assessment (including its innovative focus on risk drivers and the "cause–effect relationships" that define them, the emphasis on a systems-first approach, the opportunities it provides to distill "entry points" for adaptation responses that strengthen resilience at multiple points in a system, and its participatory and flexible process).

4. Applied method: what have we looked for?

The study consists of three cases: Paris in France, Klepp in Norway, and the river harbors in the Upper Rhine region of France (see Table 2). The cases cover three different risk pathways, and a large variety of policy sectors, actors, and instruments. The great variation in the characteristics of the selected cases illustrates what characterizes transboundary risk: this is a policy topic with very large differences in how the risk materializes, which drivers create the risk, and which actors are affected; that is, significantly more complex than is normal for many of the conventional forms of local climate risks. Our aim in selecting these particular cases has not been to cover all varieties of transboundary climate risks, but to illustrate the magnitude of variation.

All cases were based on the Impact Chain framework for structuring the work of analyzing climate risks. This framework consists of seven stages of action: (1) scoping, (2) developing impact chains, (3) identifying and selecting indicators, (4) data acquisition and management, (5) normalizing indicators, (6) weighting, and (7) aggregating indicators and components (Hagenlocher et al., 2018). The first three are by nature highly participative, whereas the latter five are highly operational (Fritzsche et al., 2014). For a detailed presentation and discussion of the seven stages, see Petutschnig et al. (2023) in this special collection. When applying this framework to the three cases, we used an adapted version of the protocol developed by Harris et al. (2022) for assessing transboundary climate risk in case-study research.

The process starts with scoping and classification, to define and characterize the system of concern, identify the key actors and relationships between them, and select one or more transboundary climate risks as the unit of analysis based on their significance. In this study, the three cases were selected and/or initiated by the research team based on their potential to depict transboundary climate risks at the outset and they were therefore classified as "transboundary climate risk centric," with the potential to advance the state of knowledge accordingly.

The next three stages are risk assessment, risk ownership and evaluation, which are interlinked with several feedback loops. This study used two different assessment approaches. The Paris case study performed a full technical risk assessment by following all steps in the original impact chain methodology, including both qualitative and quantitative evaluation of exposed or vulnerable system components. The Klepp and Upper Rhine case studies used qualitative approaches and thus performed a reduced version of the original impact chain methodology. They did detect important links and nodes of the impact chain but did not have enough data or well-known nodes and links established to go in depth with a full technical risk assessment to select indicators and quantify the factors leading to risk.

The risk ownership stage explores answers to three questions posed by Young et al. (2015): Who pays for the risk, who manages (is responsible for) the risk, and who is accountable for the risk? Each question was applied to all governance scales and administrative levels in the case studies. However, the questions were rephrased in the Paris case study to better suit the political and sensitive matter at hand, i.e., climate migration. There the focus was set on who can act and who should take more action.

The next stage according to Harris et al. (2022) should be to select suitable adaptation options (the best options evolving through evaluation of the risk and knowledge of who can manage the risk). In the final stage, presentation and iteration, several meetings and workshops were held in each case to involve and inform the stakeholders in the findings and to invite actors of concern in the process to iterate the results and increase uptake in policy and practice. Due to time constraints in the UNCHAIN project, none of the three case studies was able to fully cover the last two stages—but indications were collected of where local processes were heading in terms of deciding on adaptation measures.

In all three cases, stakeholder groups were involved in formulating the research questions, in addition to improving their knowledge and understanding of the issue, through deliberate co-production (Nilsson et al., 2017). To ensure real and equal influence in addition to ownership of the results, the capacity-building process was tailored to each stakeholder group.

The three case studies have followed the protocol from Harris et al. (2022) to a varying degree, depending on the stakeholders' maturity of knowledge concerning transboundary climate risk. Some stakeholders were introduced to the concept during the case study, while others had been managing such risks for a long time—without necessarily labeling them as "transboundary climate risks."

Data to describe the implementation and outcome of the case studies was collected in the following ways:

- Participant observation by researchers (who were also involved as advisers and facilitators in the case studies) during workshops with local stakeholders.
- Analysis of relevant background material describing the policy context in which the case studies took place, such as planning programmes or other policy documents.
- Analysis of specific outputs from the case studies that could qualify as conceptual or material boundary objects.
- Post-intervention interviews with involved local stakeholders.

In the sections below, we present the individual cases using a similar chapter division: "framing," "process," "output," "outcome," and "barriers and enabling factors." For more detailed information about the cases, see a full list of individual case descriptions on the UNCHAIN website (www.unchain.no).

TABLE 2 Cases for analyzing transboundary climate risks.

Case characteristics	The City of Paris, France	The rural municipality of Klepp, Norway	The Upper Rhine region, France
Risk pathway	People	Trade	Biophysical and trade
Policy sector	Migration and integration	Agriculture and livestock production	Freight transportation and river regulation
Main actors involved	Municipality (climate division, delegation for resilience strategy, social action center)	Local authority, county, local agricultural organizations	Central Commission for the Navigation of the Rhine, the French navigation authority, local authorities (ports management)
Policy instruments	Climate change adaptation plan, climate change adaptation strategy, resilience strategy	Municipality master plan, municipal agriculture plan	International and EU rules for transportation on Rhine, European regulations on infrastructure investments, funds in new infrastructures, co-operation and communication tools
Case process	Connected to a follow-up of the city climate plan on climate vulnerabilities	Connected to ongoing processes of updating the municipal master plan, and developing a new municipal agriculture plan	Initiated by the researchers taking part in the UNCHAIN project

5. Climate migration, City of Paris, France

5.1. Framing

As a participant in the global "100 Resilient Cities" initiative initiated by The Rockefeller Foundation in 2013, Paris adopted a resilience strategy of which climate change is one of six predefined dimensions. The Resilience strategy resolutely supports inclusion at local (neighborhood scales) and encourages building citizen networks. Taken together, these strategies provide a strong foundation for better urban resilience toward climate change.

Parallel to this initiative, the City of Paris in 2012 carried out the first territorial diagnosis of climate change vulnerability, highlighting major environmental and socioeconomic risks and opportunities. At the time, climate migration was already identified as a potential transboundary climate risk the city may have to deal with in future decades. In 2015, the City of Paris implemented its first climate change adaptation strategy. The document clearly stated anticipation of climate migration as a strategic goal. The underlying objectives were twofold: prepare a welcoming living environment for newcomers, and foster cooperation both within Paris and toward other foreign territories affected by climate change. The strategy also mandated further investigation into potential climate migration flows toward the city. In the context of its new climate plan (made mandatory in 2016), which deals with both mitigation and adaptation, the city council requested in 2020 an update of its territorial climate vulnerability assessment (Cauchy et al., 2021). This comprised a standalone study focused on climate migration (Arvis and Baret, 2021).

The latter study explores the links between climate change and the international and domestic migration patterns involving Paris. It highlights that despite the progress of thematic research on climate migrations, providing quantified estimates of future migration flows toward a specific destination such as Paris remains out of reach. A logical follow-up action to this study was to keep improving the knowledge of climate migrations through case studies in Africa or Asia using empirical approaches. The City Office in charge of climate matters thus acceded to the request for an UNCHAIN case study entailing progress on climate migration knowledge and adaptation responses at the city level. The case study focuses on transboundary migration triggered by environmental and climate factors between Senegal and the City of Paris. This specific case is justified by the important colonial and diasporic links between Senegal and France.

5.2. Process

From the onset, the City Office in charge of climate matters had the formal responsibility to keep informed of the research tasks and to involve relevant stakeholders, especially when assessing adaptive capacities at the municipality level. They were also responsible for the practical aspects of organizing the workshop to the study involved stakeholders all along the impact chain from Senegal to France. Thus, remote meetings were held with stakeholders to inform about impact chain development and indicator selection. For the "sender" impact chain, Senegalese stakeholders included academics, civil servants from the Ministry of Agriculture, and researchers from Consultative Group for International Agricultural Research (CGIAR). For the "receiver" impact chain, stakeholders interviewed included academics and civil servants working for the City of Paris (adaptation division, delegation to the resilience strategy, and social action center).

In the final stage, a workshop was held under the supervision of the city of Paris to share the results of impact chain development and explore adaptation options. Because of the political sensitive nature of the issue, only the portion of the risk and adaptation responses that are "owned" by Paris were explicitly considered in the workshop. During the workshop, stakeholder mapping was evaluated, and several adaptation options were discussed in terms of their feasibility and efficiency.

5.3. Output

The case work led to the development of two correlated impact chains (cf. Figure 1). The first impact chain ("risk sender") models the components of the decision to migrate

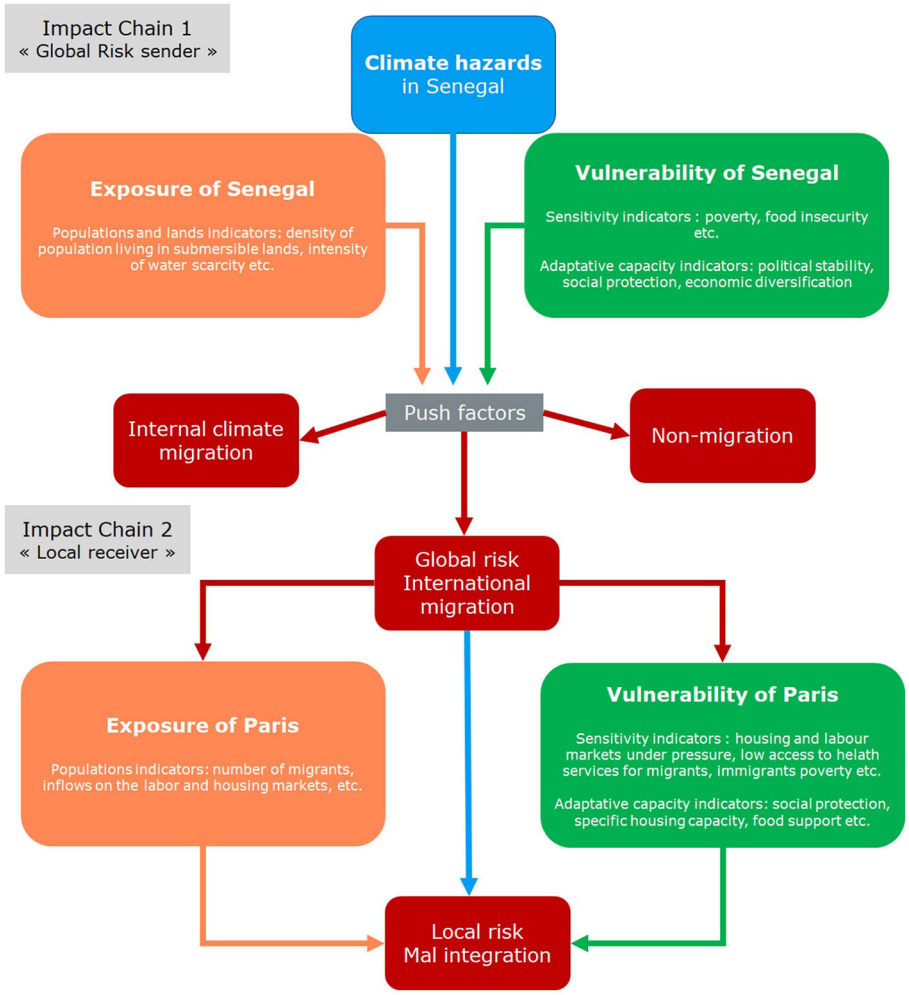

FIGURE 1
Impact chains related to the topic of climate migration for the case of Paris.

for rural Senegalese, accounting for hazard occurrence as well as the exposure and vulnerability. The outcome of the individual arbitrage is migration (internal or international), or immobility (willing or trapped). The second impact chain ("risk receiver") considers the integration process for international migrants, accounting for the exposure and vulnerability of Paris in multiple dimensions (economic, social, cultural, linguistic, residential).

The aggregation and weighting of the indicators for the first "sender" impact chain results in a *global risk score*. This score is used as the input for the *hazard* component in the second "receiver" impact chain, which does not directly reference any climate hazards. Risk scores were computed for three different representative concentration pathways (RCP) scenarios (RCP2.6, RCP 4.5, and RCP8.5). These risk scores are heavily influenced by the choice of methodology for aggregation and weighting, so their value has no significance in absolute terms. We instead interpret them in terms of their evolution over time or between climate change scenarios. The *global risk score* for the Senegal "sender" impact chain shows a logical increase from RCP2.6 to RCP8.5. For the Paris "receiver" impact chain, the variation of the risk score is low owing to the stability of the exposure and vulnerability components.

5.4. Outcomes

Defining *risk ownership* of the migrant risk is subjective and ideologically charged. On the "sender" side, the conundrum is the following: deterioration of economic conditions in the country of origin can be interpreted as a failure to adapt by the authorities, yet the root cause of climate change lies with developed countries. On the "receiver" side, the responsibility for welcoming and integrating migrants' inflows might be attributed to authorities of the host country (as it would be for "regular" asylum). However, the question could be asked about the potential sustaining role of the "sender," or the involvement, either voluntary or incentivized, of already settled diaspora from the same origin. Faced with the impossibility to clearly determine responsibility,

several stakeholders favored a capacity-based approach, replacing the question "who is liable?" with "who has the means to act?" In the following, only *adaptation options* intervening at the *local* level that emerged during the case-process and during the final workshop are presented.

In the case of migration flows, there are several facets to the adaptation mechanism. On one hand, migration is considered an individual adaptation pathway for those leaving the country of origin. Better collective adaptation in the country of origin may lead to fewer out-migrations. For the host country, adaptation to migration flows requires multiple layers of action.

Paris is solely responsible, both as a municipality and as a department, for some sectors that are key for integration such as welfare allocation, social action, cultural and local services, public spaces, etc. For housing, responsibility is shared between national programmes, which own social housing units and oversees regulations, and the city, which owns and builds social housing and allocates housing allowances.

There are shortcomings in the current organizational scheme: the so-called "Refugee coordination platform," meant to coordinate action between municipal departments and other actors (state or non-state), was canceled following the last municipal elections and replaced by an information meeting. Coordination between different entities is shifting and often lacking, even more so as much of the Partnerships are important to implementing effective actions for migrant integration.

"Integration" is multi-dimensional and refers to migrants being able to access housing, employment, having access to social services, to education or vocational training, and health services. Two key areas are housing and employment.

Housing is a key condition of both migrants' wellbeing and their social integration. This is one of the biggest challenges in the Paris area, in which the housing market is already strained and the cost of housing high. Several types of housing allowances are afforded by the City and accessible to migrants: funds and emergency housing sites operationally managed by non-profits. Yet availability and cost of housing remains a major problem. More radical solutions include temporary seizing of private vacant housing. For short-term lodgings, suggestions include partnerships with Airbnb or the traditional hotel sector or citizen participation.

Employment is a pre-requisite to having a stable income, improving access to accommodations, and fully integrating migrants in the host society by allowing interactions with natives. Solutions at City level include financial support to non-profit organizations promoting migrant employment. The city has also developed networks with the private sector to encourage employment of migrants and professional training. This private sector is particularly active, with independent NGOs, as well as caritative organizations working for integration through (self-)employment. Skill matching initiatives were mentioned to both improve migrant employment and meet employer needs in the region. Another pathway for action is to reform administrative constraints for working while awaiting judgement on residence permits, or speed up the administrative procedure, to limit the loss of human capital and self-confidence (Ukrayinchuk and Havrylchyk, 2020).

5.5. Barriers and enabling factors

In methodological terms, enabling factors include relying on co-production processes for the full duration of the impact chain (from Senegal to Paris), involving a wide range of stakeholders (institutions, researchers) who displayed strong commitment. Yet, the timing of the study, coinciding both with the COVID-19 pandemic, French presidential elections, and the Ukrainian refugee crisis, limited the amount of involvement from authorities.

Barriers to deploying the impact chain framework are significant, starting with its complex and data-intensive nature. The method incorporates some major assumptions, such as the transition between the two impact chains. The "receiver" impact chain does not use a climate hazard but a cascading anthropological hazard (migration), which implies that the risk induced by emigration from Senegal toward any destination is anything but precisely predictable in a context of climate change. Indeed, even if the choice of destination is influenced by some factors yet well identified (distance, network, former colonial link...), climatic factors bring different results on emigration rates (Beine and Parsons, 2015). The second impact chain does not focus on Senegalese immigrants, but on global migrant inflow. Finally, impact chain outputs are intricate. The global risk score obtained from aggregating indicators has no intrinsic value. It is only significant when interpreting the variation over time and through several scenarios.

6. Import of soy in husbandry production, Klepp municipality, Norway

6.1. Framing

Klepp municipality is a rural and a medium-sized municipality in a Norwegian context, with around 20,000 inhabitants. The municipality has an area of 115 km^2 and agriculture takes up 67% of this. Klepp is situated in the south-west part of Norway in one of the most productive agricultural regions of Norway. The main production is gras for local animal fodder, followed by corn, vegetables, potatoes, and vegetable production in greenhouses. The area has a wide range of animal husbandry: dairy cows, beef cattle, sheep, pigs, and poultry.

Prior to the UNCAIN project, Klepp municipality had started the process to revise both the agriculture plan and the municipal master plan. Rogaland county invited Klepp municipality into the UNCHAIN project based on a previous project in which the impact chain framework had been used to analyse climate risks at the county level (Jansen et al., 2019). The Klepp case had a twofold research question: (1) How can regional governments best help municipalities in analyzing climate risk; and (2) how can a municipality analyse transboundary climate risks? The case was limited to husbandry production. To support the needs of the local planning process, we included the task of assisting Klepp municipality to also address conventional local climate risks in connection with making the local agriculture plan.

6.2. Process

The case project was built around the municipality's progress plan and milestones for their planning processes. The municipality was responsible for the practical aspects of organizing meetings and workshops and selected and invited local actors to be involved. The county municipality acted as coordinator for the project, and together with the county governor guided the municipality in its work with analyzing climate risk and reflecting on options for climate change adaptation, while the researchers acted as advisors and facilitators on how to analyse climate risks.

Two information meetings were held prior to the actual risk assessment process: One with key-representatives of the administration in the municipality together with representatives of the county municipality and the county governor, and one with the municipal council. The main activities in the risk analysis process were two workshops with stakeholders from the local and regional municipality (administration and elected representatives), the county governor, and representatives from the agriculture sector. The later included representatives from regional and local agrarian organization, Norwegian agricultural advisory service, the dairy company Tine, Horticultural association—department Rogaland, and the Norwegian agricultural cooperative.

In the first workshop the stakeholders worked in groups to map out local hazards, vulnerability, exposure, and analyse local climate risks for the agriculture production, and to start discussing possible adaptation measures. One group started preliminary work on transboundary climate risks where they discussed possible risks linked to imported commodities.

The second workshop was committed to transboundary climate risks. Prior to the workshop a flow chart depicting the supply chain of resources going into the local farm from an international level was developed by the researchers in collaboration with the stakeholder representatives that discussed transboundary climate risks during the first workshop by means of direct contact through telephone and email. The flow chart was used as an instrument to single out which "nodes" and "links" may be exposed to climate risks and which import commodities to prioritize for further analysis.

Subsequently, interviews were conducted after the second workshop to follow up key stakeholders from the municipality, regional government, and the regional agrarian association on how they perceive local risk vs. transboundary climate risks and if they used the results.

6.3. Output

The concrete output of the case was two separate reports written by the researchers, one about the conventional local climate risks (Holm and Aall, 2021) and one about the transboundary climate risks (Holm, 2021). The core knowledge that came out of the latter was a flow chart developed with stakeholders depicting the flow of input factors for husbandry production (cf. Figure 2). The flow chart was presented as an indicator for climate risks, informing the stakeholders of which elements in the value chain that might be affected by climate hazards, and then let this be a basis for discussing at the workshop possible consequences regarding transboundary climate risks and subsequent needs and options for adapting to such risks. Based on the information that emerged in the flowchart, most attention was paid to risks linked to the heavy dependence on imported soybeans to produce concentrated feed.

During the workshop and the subsequent interviews of some of the key actors, options for adaptation strategies were discussed covering the whole scale from reactive, protective, preventive, to transformative strategies. Food security through national storage facilities was discussed as a reactive adaptation strategy. Then the overall preparedness and capacity to withstand a food crisis (e.g., disruption in supply chains) is enhanced. When it comes to securing the import of soybeans the Norwegian government has not undertaken a responsibility. However, they have a responsibility through the agricultural settlement that Norway should be more self-sufficient.

A protective measure could be to spread imports of soybeans from more countries than Brazil and Canada, which currently covers all imports. In the event, this could mean that Norway would have to give up its environmental protection motivated policy of only using non-GMO (genetically modified organisms) soybeans to produce concentrated feed.

Adaptation options, situated more toward the preventive and to some extent transformative end of the scale, were also mentioned. One would be to increase or switch to Norwegian-produced protein source to produce concentrated feed. Another option would be converting to organic farming to replace some of the imported (soybean-based concentrated feed) with local grazeland) means of production. The option of switching from livestock production to other forms of agricultural production (e.g., vegetables) was also mentioned.

The workshops, meetings, interviews, and communication in general happened digitally during the Covid pandemic. Even though digital meetings and digital tools can create good workshops, the ability to sit together, create connections, discuss, and draw conclusions was lost. Working with such a broad set of stakeholders their knowledge and experience with digital meetings and tools varies greatly and always create interruptions during workshops and discussions.

6.4. Outcomes

The project was carried out as part of two ongoing and independent of the UNCHAIN project local planning processes: (primarily) an agriculture plan and (to some extent) the municipal master plan. Both plans were submitted for consultation after the project was finished, but draft versions of the planning documents give indications of possible outcomes.

A first level indicator of a possible outcome related to is the fact that the first report that came out of the project—on the local

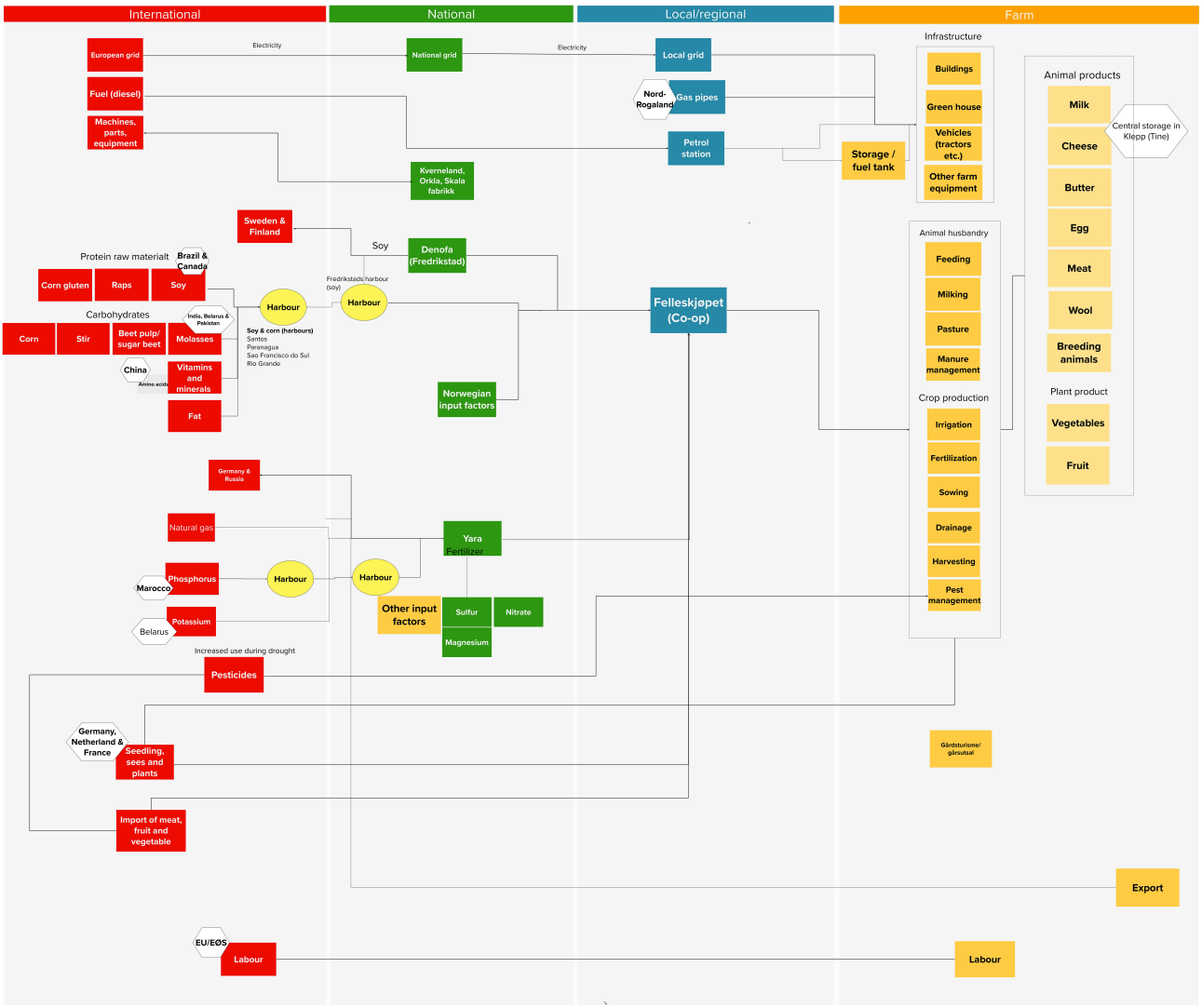

FIGURE 2
A flow chart of input factors for livestock production in Klepp municipality in Norway developed in dialog with and used to discuss among local stakeholders the transboundary climate risks and adaptation options.

climate risks (Holm and Aall, 2021)—is linked up in the draft web-version of both the *agriculture* plan[1] and the municipal master plan.[2]

In the municipal master plan, climate risk is thoroughly discussed in chapter 10 "Long-term land-use and transport development."[3] The UNCHAIN-project is referred to, and a combined summary from the two workshops—on local climate risks and transboundary climate risks—is presented (cf. Table 3).

6.5. Barriers and enabling factors

The flow chart presented in Figure 3 was acknowledged by the non-researchers involved in the workshops as a good tool for creating an understanding of what local as well as transboundary climate risk can entail and form the knowledge basis to develop ways of how to relate to the various forms of climate risk.

Working with a broad set of stakeholders across the public sector and the agriculture sector helped to identify important nodes and links through the supply chain. Furthermore, this also helped to identify key stakeholders that already had more knowledge about the threats and vulnerabilities to specific imported goods (e.g., soybeans) and could drive the discussion and development

1 https://pub.framsikt.net/plan/klepp/plan-afe5d8e8-10a1-43d6-a0c0-18cbdc9727aa/#/generic/summary/62f81e85-1686-4f1a-bc2d-85b410f72f44 (in Norwegian).

2 https://pub.framsikt.net/plan/klepp/plan-20956848-7c9e-4d7b-ab71-3ebcc6cf4683/#/generic/summary/2771bbbd-f536-4f2b-beeb-25dcc5708e72 (in Norwegian).

3 https://pub.framsikt.net/plan/klepp/plan-20956848-7c9e-4d7b-ab71-3ebcc6cf4683/#/generic/summary/7b052c17-6670-426b-998b-80249759c65a (in Norwegian).

TABLE 3 A summary of the workshops on local and transboundary climate risks presented in the draft version of the municipal master plan of Klepp municipality.

Hazard • Increase temperature • Longer growing season • Change in temperature (on-off winter/spring frost, periods with thawing and freezing) • Precipitation: increased frequency and intensity (extreme precipitation) • Floods (flooding due to rain) -> increased runoff (emergence of cyanobacteria) • Extreme weather events/storm wind • Storm surge + rise in sea level • "Locked" weather systems	**Vulnerability** • Politics—agriculture policies (increased demand to area used to spread fertilizer), climate policies (demands for electrification) and public health policies (change in dietary habits) • Import of goods (the import of soy might decline and lead to increase in prices • Dismantling of topsoil and marshlands • Shorter harvesting season • Emerging animal diseases (ticks, pests, and fungi) • Storage capacity for fertilizer • Knowledge (lack of or wrong knowledge) • Recruitment to the agriculture sector • Poor drainage systems • Spatial planning and development that may lead to water going astray • Infrastructure (transportation, roads, supply of energy and security of supply) • Road construction and division of land
Exposure • Food security: crop failure • Arable area (soils and soil productivity) • Logistics: more difficult to drive in the field • Infrastructure: damage on buildings, power grid and transportation network • Area: more prone to erosion, damage on pasture which can change the length of the grazing season, the mowing and number of mows is changed due to climate change • Animal welfare: more illnesses, pests, and invasive species • Water course: erosion, draft • The soy imports to fodder • The trading markets • Peatlands • Culture landscape	**Risk** • Loss of jobs—financial vulnerabilities that cause an increase in costs and psychological stress • Crop failure/loss of arable land (reduced food security, soil compaction that damage the soil structure and crop production) • The systematic use of pesticides may increase • Deterioration of ecosystem and ecosystem services • Floods, erosion, stormwater, changed water flow • Biodiversity loss • Disruption in the transport network • Reduced fodder production • Sand dunes disappear • A constant high-water level • Overgrowth

of the impact chain map further. By including the project into the processes of renewing the agriculture plan and the municipal master plan it became easier for the municipality to incorporate the outcome of the risk analysis into conventional policy making process, thereby increasing the chances of making adaptation to transboundary climate risks a salient issue on the policy agenda in line with that of conventional "local" climate risks.

At the same time, both the researchers and the users recognized that better tools and access to more relevant data is needed to develop effective policy measures.

But an even more important barrier is the absence of transboundary climate risks on the national climate change adaptation agenda, and thus the necessary clarifications of how the responsibility for addressing this type of risk is to be distributed between public and private policy actors, and in the next round the distribution of responsibility between the different geographical levels of policy actors. Such clarifications must be made specifically for different policy sectors; in this case within the agricultural sector—a challenge that was highlighted by the actors who participated in the second workshop.

7. River transportation, Upper Rhine region, France

7.1. Framing

The Rhine is evolving toward a rain-fed river (Parmet et al., 1994). The winter discharge increases, which can have consequences for safety, and summer discharge decreases with consequences for shipping, industry, agriculture, and ecology. In 2018, the Rhine transport sector experienced an unprecedented low-water crisis, during which large cargo vessels were no longer able to navigate on certain sections of the river. This led to a major disruption in the inland waterway transport. The severity of this crisis, which was the result of several months of drought, reinforced by heat waves and low rainfall over the same period, caused an upheaval in the inland navigation sector.

The transboundary aspect is the result from the biophysical dimension of the river as it crosses several countries but also from trade and political dimensions. The Rhine has an international status, which was decided 200 years ago driven by trade considerations. Environmental issues won consideration in the 1970's and got to a peak with the Sandoz chemical spill in 1986, a major environmental disaster caused by a fire and its subsequent extinguishing at Sandoz agrochemical storehouse located in Basel-Landschaft, Switzerland, which released toxic agrochemicals into the Rhine river. The international restoration plan is an example of multilevel agentively illustrating the willingness to respond in a successful way to a major environmental crisis. The question is whether such willingness can be repeated in this new type of transboundary crisis when the problem is caused by global climate change, not a specific local critical event.

7.2. Process

Taking advantage of the relationships established through a previous project addressing the Upper Rhine sensitivity to climate change (the project Clim'Ability financed by the Interreg V program from 2016 to 2022), the research team was able to establish a co-operation with the port authorities of the Upper Rhine region. This process has been enriched by the so-called "Inventive Design Method" (Cavallucci, 2018; Coulibaly et al., 2022), which is a participatory engineering approach to innovative solutions for problematic situations or industrial deadlocks. The understanding of the vulnerability of the firms and the territories to low waters has thus benefited from a methodological mix: semi-directive interviews with

key stakeholders (transport providers, importers/exporters using inland waterway transport) concerned by low waters, and the implementation of the inventive design method to stimulate a cooperative understanding of the collective vulnerability to the risk.

7.3. Output

Different variables have been integrated to define an impact chain (Figure 3) which considers the cascading effects (Vinke et al., 2021) and the possible multiple effects of low waters on shippers, firms, and ports to make goods circulate.

Some of the other significant outputs were a collective decision about the issue that federates people, who are usually in economic competition; a collective map of partial solutions provided to resolve this common issue; and a map providing the distribution of knowledge and ignorance.

The crossing of data from individual interviews and collective situations made it possible to identify areas of ignorance among the stakeholders, as well as implicit collective norms.

From the above-mentioned material, different adaptation strategies have been proposed, discussed, and weighted through. We distinguish three main strategies: reactive adaptation, transformative infrastructural adaptation, and radical system transformation. Each strategy is based on specific technical, organizational, institutional modalities and a certain degree of knowledge and know-how: that is why we firstly display the possible strategies and secondly the organizational and technical solutions which may be mobilized by the different strategies (Gobert and Rudolf, 2023).

The *reactive* adaptation strategy corresponds to an immediate response to the crisis. This adaptive answer is limited to technical and organizational reactions (like short-time work, decreasing of the volumes transported). Stakeholders may attempt during the crisis period to shift to another transport, but flexibility needs to be prepared through social skills (network, confidence, etc.) to overlap the constraints due to the crisis (lack of drivers, increase of the demand, etc.). Agreements between transport firms must be structured during the crisis.

The *transformative infrastructural* adaptation is the kind of solution which convinced most of the stakeholders involved, i.e., strategies to increase the water level and overcome low water levels. Examples are using the Lake Constance as a water reservoir, creating of new water storage areas, and deepening of the channel at Kaub and Maxau. strengthen the vision that business as usual. This adaptation pathway, which is not even supported by robust scientific studies, improves the existing situation, makes more efficient the inland waterway transport and the associated logistics for all stakeholders (except the Rhine, as these solutions are considered as impactful). It reveals the path dependency regardless of impacts on the Rhine ecosystem as well as the weakness of the players. These infrastructural solutions are a means to redistribute the responsibility between stakeholders and to discharge individuals from a too heavy financial and organizational changes.

The *radical system* transformation takes into consideration that value and supply chains must be modified for more circularized flows and an integration of climate risk related uncertainties. This variety of the adaptation discourse was promoted especially by environmental representatives or authorities regulating the Rhine waterway.

7.4. Outcomes

The process as well as the outcome legitimates the harbor's authorities to pursue their work to gather the strengths of different stakeholders and to mobilize about the low water issue. They adopted different tools (information, lobbying and stakeholders gathering). They have started to edit a Newsletter, which was distributed at first in an inner circle. While they received positive feedback from different authorities, they decided to distribute widely. They enlarged the process of reflexion to the harbors of the Upper Rhine Region. The collective building is then in process. The harbors authorities are going to apply for a follow-up research project in the Interreg Program VI.

The harbor authority and Voies Navigables de France (the authority managing navigation on French rivers played the role of policy entrepreneurs and boundary organization between the stakeholders involved in the goods transport, the researchers, and the national as well as sub-national authorities in charge of the inland waterway transport management. They occupy a position of mediators between different scales. For example, they must be able to alert, relay, mobilize and influence other levels to ensure local ownership and satisfy their constituents. This is evident in the case of work on the infrastructure that cannot be undertaken by them. For that, they must push this issue on the agenda of other authorities and scales so that the low-water issue could be considered and tackled. On the other hand, the fact that the "hard" option (i.e., the transformative infrastructural adaptation strategy—prevails to a very large extent also suggests that local players, including port authorities, may be reluctant to assume some responsibilities.

Their way of asserting themselves as owners of the risk is expressed by commissioning scientific studies on parallel research, infrastructures or equipment which could decrease the pressure on the Rhine River. This openness has undoubtedly benefited from the approach taken by the researchers of the Interreg V projects, relayed by the UNCHAIN project, as evidenced by their current involvement in an Interreg VI research project carried out by seven Rhine ports.

7.5. Barriers and enabling factors

Transport modes have followed historical and sectoral logics. While it may seem logical to respond to the crises affecting shipping with intermodal responses, the reality of the transport modes does not easily allow this. Shipping has its own characteristics and

advantages according to the goods transported and the transport modes (in bulk/container). Other transport modes also follow their own logics, constraints, and inertia. First and foremost, transferring all containers on roads or rail is impossible because of the considered volumes and the types of goods. Alternatives to shipping products on the Rhine River are expensive for shippers. It also appeared complicated to change the transport mode if the transport providers impacted by the crisis did not have previous contracts with rail or road transport companies. Moreover, some resources may have been lacking. Legislation may hinder the transfer as well as technical and organizational reasons. For example, the rail paths are considered as not sufficient and overloaded to assure the transferability. The lack of skilled truck drivers is a European issue, which reveals itself particularly symptomatic when a crisis breaks. That is why reacting to this crisis requires collective agility and deeper and longer work between stakeholders: firms which must transport goods or resources, carriers, port authorities.

Building trust between stakeholders is a very significant resource. For this purpose, it is particularly strategic to enlist individuals, who are recognized and have the legitimacy to gather stakeholders (social and symbolic capital). The role was mainly played by the Strasbourg port authority, which have attempted to recruit participants and to find ways so that the collective process could be prolonged. However, obtaining a collective involvement until the end of the process requires time and human resource for private companies. The involvement stays very partial and dependent on the co-organizer.

The transboundary character of risks involved in situations of low- (or high) water of the Rhine does not seem to ease to development and implementation of effective adaptation measures. Indeed, although the local stakeholders involved can try to attract the attention of national and international authorities to deal with the subject of low and high waters, inland waterway transport is above all dependent on the global trade system. The limited institutional capacity to influence in a positive way the resilience of the Upper Rhine River transport capabilities appears to put further pressure on an infrastructure system already overburdened by a global market.

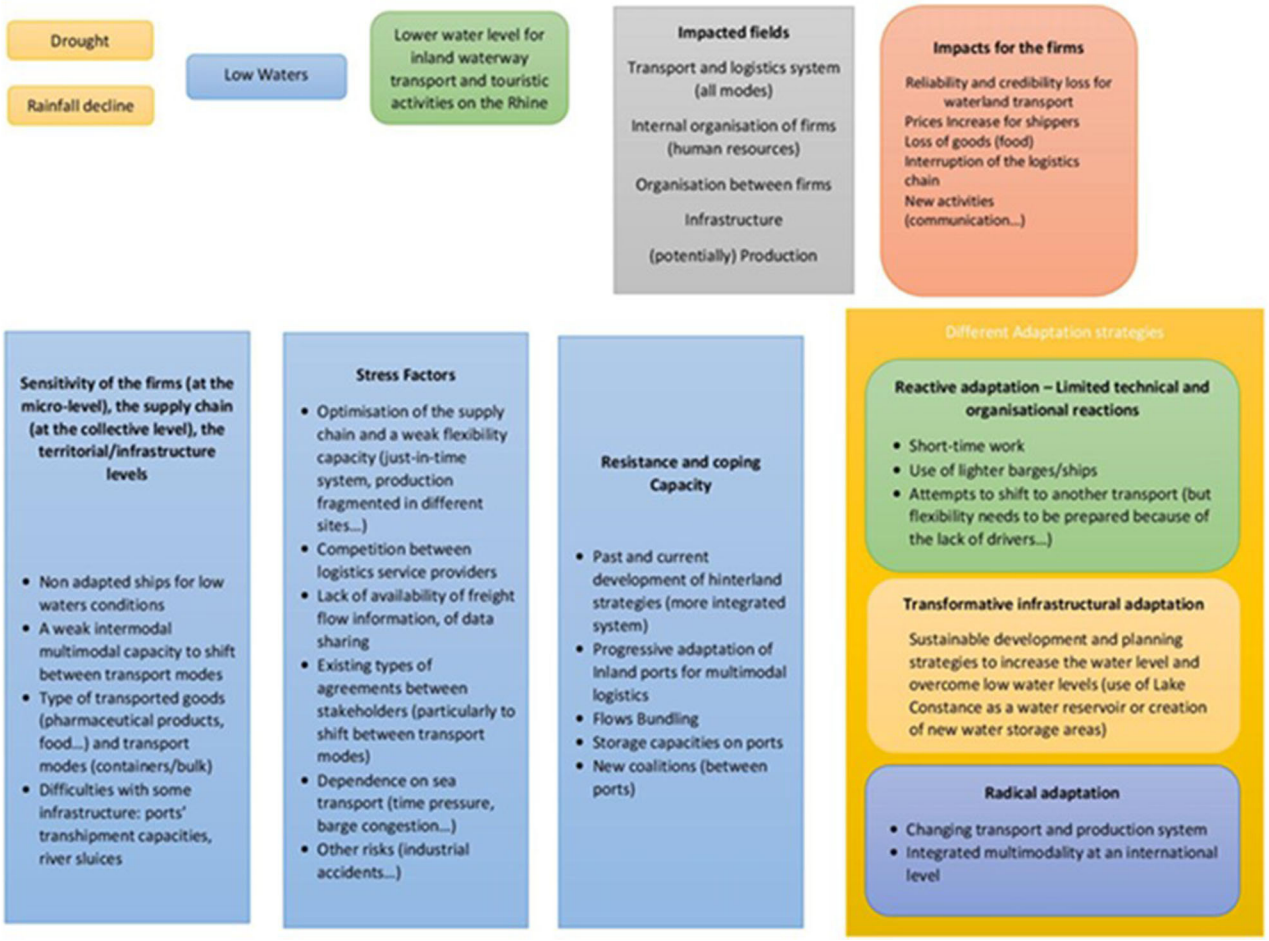

FIGURE 3
Impact chain produced to define with stakeholders the different issues raised by low water from the local level until the international supply chain.

8. Discussion: problems and prospects of putting a new global environmental problem on the local policy agenda

The cases presented above illustrate both problems and prospects for how transboundary climate risks—characterized by different variations of being a global or non-local environmental problem—can be translated into a local setting and put on a local policy agenda.

As stated by among others, Hägerstrand (1991), a crucial prerequisite for local actors—like local authorities—to address genuinely global environmental problems, like transboundary climate risks, is the ability to successfully translate the "global" into a meaningful local context. This implies understanding how complex interactions between cascading impacts at a global level—both those catalyzed by climate change and those generated by other crises and global dynamics—drive the creation or amplification of risks as well as opportunities at a local level. An increase in the number of immigrants (cf. the Paris case), an increase in the price of imported fodder in livestock production (cf. the Klepp case), and the threat of disruption to the import and export of goods (cf. the Upper Rhine case) are all very concrete translations of an externally created challenge (impacts of climate change located outside the area of investigation) that can trigger both negative impacts and positive opportunities in a local context.

The flowcharts derived from application of the impact chain framework (cf. Figures 2, 3) has proven useful for local actors as an illustration of how impacts that originate beyond the jurisdiction of a locality may create local risks which may require at least some level of response from local authorities. Thus, the impact chain framework appears to have the potential to become a boundary object for putting transboundary climate risks on the local policy agenda (notwithstanding the finding that the full instrumental version, which was initially developed for the purpose of analyzing conventional forms of local climate risk, cannot be applied in every case). Flow charts—such as the one produced in the Klepp case—clearly show both the extent and complexity of connections between the local and the global, and at the same time provides a basis for reflecting on the extent and type of climate risk that local livestock production faces, in addition to conventional local risks from physical climate impacts.

The logic underpinning the impact chain framework, of systemising and diversifying climate impacts into "links" and "nodes," makes it a relevant instrument for illustrating and assessing the complexity of transboundary climate risks. At the same time, precisely because the impact chain framework is so flexible, one risks falling into the trap of adding too much complexity to the analysis, which can make it difficult for policymakers and the layman user to relate meaningfully to the analysis. Thus, given that the impact chain framework was originally developed for analyzing local climate risks, alternations are needed to make it a more tangible and usable framework for also addressing transboundary climate risks.

The three cases illustrate clearly that local stakeholders can be made aware of the concrete and local challenges that transboundary climate risks can create, and that such risks should and must be addressed. They also demonstrate that due to the complexity of analyzing transboundary climate risks, applying techniques of knowledge co-production is an important prerequisite for creating actionable knowledge emerging from a risk analysis. Still, the cases also demonstrated several well-known barriers for conducting a robust analysis and producing actionable knowledge, such as lack of accessible and relevant data, lack of local competence, and lack of administrative capacity. The term "well-known" reflects that these are barriers relating to institutional and social conditions which we find mentioned frequently in the general literature on climate change adaptation (Amundsen et al., 2010; Biesbroek et al., 2013; Eisenack et al., 2014).

When facing the challenges involved in addressing transboundary climate risks, policy actors in the three local cases discussed various options for adaptation strategies, ranging from the more instrumental and technical reactive and protective measures, toward preventive and even transformative measures. The need or proposal for more transformative actions was particularly clear in the Klepp case, where actors also discussed a total restructuring of agricultural policy (toward organic farming) as one possible response, in addition to more traditional measures such as replacing imported soy with Norwegian-grown protein sources for use in concentrate. A possible consequence of transboundary climate risks increasingly being considered within the risk and vulnerability assessments that inform adaptation plans and strategies could therefore be that adaptation becomes more transformative over time. Even when infrastructural solutions that enable the delegation of responsibility to others are preferred, as in the Upper Rhine example, stakeholders recognized the need for a more balanced management configuration, where technical and infrastructural measures are combined with organizational and governance resolutions (Hoang et al., 2018). The organizational solutions are essentially based on inter- and multi-modality. The principle is: when the water level no longer allows inland waterway traffic, the transport provider switches to another mode of transport. This requires a transformative act, while considering a shared solution in the absence of reactivity from the national and international level.

TABLE 4 How addressing transboundary climate risks can help to unify the adaptation and mitigation part of climate policy.

		Cause	
		Concentrated	Dispersed
Impact	Concentrated	Adaptation to conventional "local" climate risks	Adaptation to transboundary climate risks
	Dispersed		Mitigation of greenhouse gas emissions

The three cases illustrated several challenges and barriers for adapting to the local risks catalyzed by transboundary climate impacts. The main barrier concerns access to data regarding the localized risk. This became especially problematic when assessing the "source" of the risk, cf. the Paris case, where data in Senegal were not easy to collect, but can apply to any context of transboundary climate risk (given the source is, by definition, beyond the recipient's jurisdiction). As demonstrated in the Klepp case, it is difficult to establish to what extent the challenges faced by farmers in Klepp, in relation to transboundary climate risks, differ to those facing all Norwegian livestock farmers. This breaks the logic of conventional local climate risk assessments, which aim to bring out local variation in the components that create the local climate risk—i.e., local hazards, local vulnerabilities, and local exposures.

One of the most exciting and innovative opportunities that presents itself as a result of local authorities engagement in the topic of transboundary climate risks is that it can contribute breaking down the cleavage between the adaptation and mitigation parts of climate policy (Table 4). A dichotomy between mitigation and adaptation was already well established by the early 1990s when the United Nations Framework Convention on Climate Change (UNFCCC) was established, giving adaptation a subordinate role in relationship to mitigation (Schipper, 2006). One aspect of this dichotomy is that the adaptation part of climate policy is often framed as a local environmental problem—a climate risk that manifests itself locally and therefore must be handled locally—while the mitigation part is more frequently framed as a global environmental problem that requires international targets and agreement. An institutional repercussion of this distinction is that adaptation is often handled by civil defense-related institutions, with a mandate to protect business-as-usual, while mitigation in most cases is dealt with by institutions with a mandate to enact at least some changes to business-as-usual (Groven et al., 2012).

Therefore, under current conditions—with few initiatives at the national level to seriously address transboundary climate risks—the most important contribution from local authorities to the better management of such risks might be to formulate requests for political initiatives at the national level (e.g., requests to change national agriculture policies in the Klepp case) and the supranational level (e.g., the participation of the city of Paris in the Mayor Migration Council). Such requests and initiatives may point toward adaptation measures that are more transformative than incremental in nature.

9. Conclusion: some critical factors for successfully addressing transboundary climate risks

A growing number of countries are in the process of considering transboundary climate risks in their national adaptation policy agenda (Beringer et al., 2022). However, even if the sub-national actors involved in the three cases showed strong interest in analyzing and addressing transboundary climate risks, it remains an open question whether such authorities can and should play an equally central role in addressing transboundary climate risks as do in the case of local climate risks.

Assigning responsibility for managing transboundary climate risks exclusively to national authorities may increase the risk of conflicts between measures to reduce local climate risks (frequently developed and implemented by sub-national authorities) and transboundary climate risks.

On the other hand, assigning responsibility for managing transboundary climate risks to sub-national authorities (to the same extent currently as for local climate risks) may lead to a situation that far too little is done, since transboundary climate risks must also involve national and supranational governance and international cooperation, particularly on issues like migration and trade.

The authors of this paper therefore advocate a strong partnership between the different levels of governance, and between public and private-sector stakeholders, in adaptation to transboundary climate risk; a partnership that will have to be closer and more mutually binding than that already established in most countries to adapt to local climate risks. It is therefore crucial that national governments explicitly account for transboundary climate risks in their national adaptation agendas, and as part of their process in determining "ownership" of such risks, decide on the role sub-national authorities should play. This choice will also affect the role of local authorities in managing local climate risks due to the interlinkages between them. Depending on the role sub-national governments are assigned, national governments need to finance the development of tools that sub-national governments can use to analyse transboundary climate risks akin to those developed to analyse conventional local climate risks (cf. the type of tools provided by the many climate service centers).

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: www.unchain.no.

Author contributions

Conceptualization: CA, KH, and FL. Data curation: CA and MJ. Investigation: TH, AC, FR, MJ, JG, BA, and MB. Methodology: CA, AC, MJ, and KH. Funding acquisition: CA. Project coordination: CA, AC, and MJ. Supervision: CA and KH. Visualization: CA, TH, JG, and AC. Writing—original draft: CA, TH, AC, FR, KH, MJ, JG, FL, BA, and MB. Writing—review and editing: CA, TH, AC, FR, KH, JG, FL, BA, and MB. All authors contributed to the article and approved the submitted version.

Conflict of interest

AC, BA, and MB were employed by Ramboll France SAS.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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