Can data cross frontiers? Challenges and drivers for cross-border data sharing for disaster risk reduction

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Data sharing is a key driver of disaster risk reduction (DRR) and supports the resilience of cross-border regions. However, data sharing across borders remains challenging, and only a limited number of regions have significantly progressed in this area. A better understanding of the challenges of data sharing in cross-border DRR ecosystems is therefore needed but remains overlooked in the literature. This research, which is based on a qualitative and collaborative design, focuses on the Italy−France border, which has been pursuing efforts to create a cross-border data ecosystem for DRR in recent years. This study consists of a comprehensive analysis, which is primarily based on qualitative interviews, observations, and archive analyses. It outlines how the cross-border setting exacerbates the challenges of data sharing for DRR. Cross-border DRR actors struggle to build trust around the data and adopt a unified data strategy across borders. However, in the face of these challenges, DRR actors are gradually transforming their DRR practices by incorporating cooperative, trustful, and inclusive relationships. Our findings contribute to a more situated understanding of data sharing at borders and call for greater consideration of border settings and the agency from practitioners involved in data sharing for international DRR.

KEYWORDS

disaster risk reduction (DRR), data sharing, cross-border cooperation, emergence, disaster management

Introduction

On 13 August 2023, heavy rains in the Savoie region of France caused mudslides in Bardonecchia, Italy.[1] In addition, rising temperatures caused major landslides in the Alps, such as the one that occurred at La Praz, near Modane, in the Maurienne Valley on 27 August 2023 (Bottelin and Baillet, 2024). These events disrupted the railways and motorways that facilitate transport, the mobility of workers, and economic exchanges between Italy and France. The main direct rail link between France and Italy is currently closed and will remain closed until the middle of 2025. These examples illustrate the vulnerability of cross-border regions to disasters.

Cross-border regions are characterized by artificial or natural divisions, such as rivers and mountains. They tend to be economically and politically marginalized compared to country centers (Şlusarciuc, 2015). However, they often host critical infrastructures such as highways, dams, and industrial and energy facilities. They can even attract exploratory investment, as in

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1 For more details, see the BBC archives.

the case of the economic corridor being developed between Pakistan and China (Lim, 2019). For these reasons, the ability of border organizations to prevent and respond to disasters has become a major concern for not only local and national authorities but also international organizations (Abad et al., 2018). Therefore, all these actors have been working to support cross-border DRR, which consists of identifying and preventing risks that can cause disasters (Palliyaguru et al., 2014). DRR also encompasses collective response to these disasters.

Data can drive DRR cooperation across borders (Kanbara and Shaw, 2021). First, as a digital resource, data is easily replicated and shared. Second, multiple data sources are needed to understand and prevent disasters (Petrenj et al., 2013), which implies the need for cooperation to aggregate and harmonize data. As illustrated by the case of Bardonecchia, in which the heavy rains that struck the Italian village started on the other side of the border in France, data calls for cooperation.

In short, data sharing does not amount to sporadic sending or receiving of datasets. As explained by Jussen et al. (2023), it refers to the collective organization of data access and management within a given ecosystem. Data sharing generally refers to the exchange, transfer, or provision of access to data with the goal of enabling collaboration, improving decision-making, or creating value while ensuring compliance with ethical, legal, and privacy standards. In this sense, data sharing is sociotechnical and is not limited to technological interoperability (Liverani et al., 2018). However, the sociotechnical dimension of data remains overlooked in the literature on DRR (Petrenj et al., 2013), which has focused mostly on the technical issues of data sharing (e.g., Toro et al., 2019). While exploring these issues is important, research on the behavioral, organizational, and social challenges of data sharing for DRR is lacking (Petrenj et al., 2013).

Data sharing within ecosystems presents a wide range of behavioral and organizational challenges (Gelhaar et al., 2021), ranging from a lack of understanding of the value of data to fears about data security (Jackson and Hayes, 2016). In the context of cross-border DRR, studies fail to provide a comprehensive understanding of these challenges. The conceptual basis for DRR has been criticized for being ballistic and truistic (Nohrstedt et al., 2022). At a conceptual level, the challenges of cross-border DRR and data have remained loosely articulated. In addition, existing research tends to overlook the practical ways in which DRR actors address these challenges and develop and mobilize resources to promote cross-border data sharing.

Given the above, this work addresses the following question: "*What are the challenges of cross-border data sharing for DRR, and how can DRR actors address them?*"

The present work addresses this question by relying on a qualitative research design. We have considered the case of the Italy–France border, which has been struggling with the increasing frequency of disasters caused by landsides and mudslides in the Alps. This research is still in progress and requires further enrichment. To date, data have been collected through 30 interviews, archives, and meetings with experts and practitioners, following the principles of grounded theory (Glaser and Strauss, 1967). The findings provide a comprehensive overview of the challenges of data sharing at borders. The fragmented nature of the border exacerbates the challenges inherent to DRR, making it difficult to build mutual trust, a unified data strategy, and harmonized levels of data literacy. However, DRR actors have adapted their practices to address these challenges by proactively seeking data collaboration but also by promoting transparency, trust, and inclusivity. We then discuss the novelty of these findings, future avenues to improve the research, and their practical implications.

Theoretical background

Disasters and DRR at borders

Borders are particularly exposed to disasters and critical situations. Most borders are shaped by topological elements prone to disruptive events. For example, water zones, such as the Rhin between Germany and France or Tanganyika Lake between the Democratic Republic of the Congo and Tanzania, are subject to floods. As another example, mountains, such as the Alps between Austria and Italy or the Himalayas between China and India, are subject to landslides and earthquakes. Cross-border regions have become increasingly important for economic integration on all continents (Brunet-Jailly, 2022). They host critical infrastructures such as nuclear power plants, energy infrastructures, dams, and transport channels. Therefore, they are exposed not only to natural risks but also to man-made risks. For this reason, disasters are likely to occur at borders and are likely to cause significant economic costs. For this reason, cross-border regions – defined here as territories at the jointure between distinct countries separated by a topological or administrative border – need to become resilient. DRR practices can aid in strengthening of this resilience while achieving sustainable development by preventing new and reducing existing and new disaster risks (Palliyaguru et al., 2014). The key concepts of DRR have been discussed in the literature (Palliyaguru et al., 2014). Disaster risk corresponds to the possibility of harmful consequences resulting from the interactions between hazards and vulnerable conditions (UN-ISDR, 2009). In this context, vulnerability covers both exposure to hazards and the capacity to address them. In other words, vulnerability is the combination of, on the one hand, the degree of exposure of a system (societal, productive, etc.) and, on the other hand, its capacity to prepare for and respond to the hazard (UN-ISDR, 2009). Importantly, disasters are not purely natural. Indeed, floods, fires and landslides can be bolstered—if not triggered—by urbanistic design and human intervention.

On the basis of the review provided by Palliyaguru et al. (2014), DRR can be approached as a set of four interdependent strategies, namely, (i) eliminating (avoiding risk), (ii) mitigating (reducing the impact of hazards, as well as their frequency, intensity, and scale), (iii) preparing (developing resilience and response capacities and plans), and (iv) advocacy (favoring good practices through influence). Mitigating disaster-related risk thus depends on decades-long projects that involve international and national planning (McConnell and Drennan, 2006). Additionally, advocacy is a long-term endeavor of DRR because it consists of lobbying institutions, organizations, and communities.

Furthermore, the management of crises and disasters at borders requires collaboration between a large spectrum of organizations, such as companies, administrations, agencies, communities, and authorities, from multiple countries and sectors (Ansell et al., 2010; Ansell and Boin, 2009). In line with this view, DRR at borders involves a large spectrum of stakeholders, from local to national and international actors. At the local level, municipalities are not only

responsible for the safety of citizens but also access to commodities, including water and transportation. Communities are involved in promoting the well-being and sustainability of economies, which also depend on infrastructure. At the national level, states are responsible for the protection of their population and the mobilization of their emergency actors. At an international level, transborder organizations can encourage—legally or not—the use of good practices. Increasingly, DRR actors have aimed to integrate diverse processes and approaches to address disaster risk but without significant success (Abad et al., 2018).

Data for DRR

As explained herein, DRR involves radically diverse organizations, ranging from local administrations and nonprofit organizations to companies that provide insurance services, manage critical infrastructures, or distribute essential goods. For these organizations, a critical resource for managing disasters is reliable data (UNDRR, 2015). Scholars have presented this data as a crucial but still underused resource (Sarker et al., 2020; van den Homberg et al., 2018).

Information needs for DRR are particularly broad, which means that an exhaustive list of these needs hardly makes sense (Serje, 2011). However, we provide here some examples of the diversified data used for DRR, ranging from natural and industrial risk data to demographic and health data. DRR actors primarily process datasets on natural hazards (such as the level of seismic risk for a specific location), weather forecasts (such as precipitation level associated to a specific events), and topological data about roads, rivers, and mountains. The data used can also include historical data about fires, landslides, conflicts, floods, etc. For instance, the European Forest Fire Information System (EFFIS)[2] provides data sets about fire danger forecast, including drought intensity. Sensors and data from social media can include real-time and/or geolocalized data about ongoing events. Additionally, technology democratization helps include organizations' crowdsourced data about ongoing events (Salvati et al., 2021), such as pictures of damage. Murex[3] is an example of a platform that shares pictures of material damages after floods.

However, data collection and analysis for DRR remain challenging. Organizations involved in disaster response rarely prepare the data in ways that can address all their informational needs (van den Homberg et al., 2018). As a result, organizations miss timely access to complete, precise and standardize data. For this reason, organizations need to work on data preparedness (van den Homberg et al., 2018) by sharing data before a disaster strikes (Sarker et al., 2020).

The growing use of data for DRR illustrates the search for digital maturity worldwide, supported by the United Nations (for more details, see the UNDRR report 2022). While some countries around the world have been working on centralized disaster data systems, other countries have been promoting collaboration to share data. These countries have put efforts into developing data ecosystems (van Esch, 2021) and open data (Kanbara and Shaw, 2021). However, cross-border data have the potential to improve our understanding of how

global phenomena, such as climate change, shape the nature and frequency of disasters (Talebian et al., 2021). From this perspective, cross-border data sharing has become an essential driver of DRR improvement worldwide.

The importance of data sharing

In the scholarly sphere, data sharing has been investigated in a large spectrum of sectors (see, for instance, Hazell et al., 2023; Ure et al., 2009). Data sharing is not restricted to the settling of infrastructures and programs that can make data sets interoperable. Rather, data sharing, as a sociotechnical phenomenon, is complex (Liverani et al., 2018). It relies on a set of technologies whose interoperability needs to be designed and managed (Ertac et al., 2011; Jussen et al., 2023; Toro et al., 2019). Data sharing also requires specific means and resources, such as training programs, mentorships, and networks, as former research highlights it in the health sector (Liverani et al., 2018). Furthermore, data sharing requires that organizations develop data literacy (Wolff et al., 2016).

In the fields of DRR and resilience, a lack of knowledge regarding the sharing of multiple datasets has persisted (Migliorini et al., 2019). Most recent studies highlight the need for active cooperation (Liverani et al., 2018) and shared willingness to harmonize data and make it accessible to others (Migliorini et al., 2019). However, from a practitioner perspective, the situation has changed greatly in recent years. Currently, data sharing represents a major component of resilience, especially at borders.

Data sharing for DRR at borders

At European borders, projects such as ESPRESSO or GIOCONDA (Toro et al., 2019), Interreg ALCOTRA,[4] R! SK,[5] and AMIS have outlined the benefits of sharing data across borders. For example, AMIS relies on multiple datasets from Italy and France (including economic, topological, and demographic data) to predict the impacts of climate change on natural hazards on the coast of Italy and France. Additionally, the European Commission has supported the rise of data ecosystems for DRR by producing data frameworks to help organizations address the diversity of rules and standards related to data (European Commission, Joint Research Centre, 2021). Beyond Europe, the World Economic Forum (WEF) has supported the sharing of data between Turkÿe and Greece to produce an early warning system about fires. In Asia, at borders shaped by the Mekong River, cross-boundary organizations have been created to promote data sharing between countries (Thu and Wehn, 2016).

Data mutualization across borders can be used to better grasp the nature and amplitude of a risk. Once a crisis strikes, data sharing can help in the coordination of actions (Liverani et al., 2018). Even when tensions arise between countries, organizations still continue to collect and share data (Thu and Wehn, 2016), which also reveals the relevance of data sharing. However, sharing data for DRR at borders remains

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2   https://forest-fire.emergency.copernicus.eu/
3   https://www.cerema.fr/en

4   https://www.interreg-alcotra.eu
5   https://www.pitem-risk.eu

difficult in practice. Many difficulties that can obstruct data sharing have been reported in the literature, including trust and data sovereignty (Ryan et al., 2024), incompatible data standards and loose integration of data (Migliorini et al., 2019), clashing top-down and bottom-up logics (Wong Villanueva et al., 2022), fragmentation (Rivera et al., 2015).

Despite the growing interest in data sharing in the context of cross-border DRR, there is a lack of comprehensive understanding of the challenges inherent to data sharing at borders. This calls for more investigation of the nature of phenomena that can prevent data sharing. In the following section, we detail the methodology that we have followed to address the research question.

Research design

As a reminder, this work addresses the nature of the challenges of cross-border data sharing for DRR. To address this question, we used a qualitative research design focusing on the case of the Italy–France cross-border region. The research design of this work was exploratory and drew on grounded theory principles (Glaser and Strauss, 1967). Following grounded theory principles, we first identified the missed opportunities for data sharing for DRR at the Italy–France border as a primary concern for this research (Walsh et al., 2019). We then proceeded with several rounds of coding, which we describe in this section.

In this section, we describe our design choices, the research process and the challenges we met in collecting and analyzing the data. We also present our analysis practices and tools. This study is embedded in a wider collaboration with a nongovernmental organization (NGO) to conduct an action research project. This study is also inclusive and involves master's degree students (see the acknowledgements section for a mention of the project and the students).Italy–France case

To address this research question, we conducted a case study focusing on the Italy–France border region. Italy and France are separated by the Alps and share a common Mediterranean coast. From an administrative perspective, this cross-border region includes three Italian regions (Val D'Aosta, Piemonte and Liguria) and five French departments. For decades, Italy and France have pursued efforts to overcome the separation embodied by the Alps. In terms of DRR, the two countries have been collaborating to elaborate shared databases on natural risks and vulnerabilities. The Alcotra Interreg[6] project is a cooperation program between Italy and France funded by the European Commission (EC) that takes place between 2021 and 2027. It comprises projects such as Concert-Eaux (2000–2006) and Amis (2024), which both create databases that cover the Italy–France cross-border region. Concert-Eaux[7] created a geoportal that gathers data about underground water nappes in the Roya valley. Amis[8] aims to gather geographical, climatic, and socioeconomic data to model risks and simulate the impact of climate change on the Mediterranean coast, which is shared by Italy and France. Despite these efforts, the two countries still struggle

to fully use each other's data to prevent and address disasters. Despite collaborative efforts to establish common data infrastructures, a regulated and sustainable data sharing space is still lacking.

Italy and France have recently been experiencing many cross-border disasters (such as the storm Alex and the 2023 landslide). The latest disasters were the most impactful, both socially and economically. For example, in October 2020, the storm Alex struck the cross-border territory between Liguria (Italy) and Alpes-Maritime (France).[9] Only in a few hours, Alex killed and destroyed many infrastructures, including more than 20 bridges and 60 roads. The damages from Alex, which affected the population's basic needs, such as mobility, electricity, and drinkable water access, are still being addressed today. In August 2023, a major railway connection between Lyon and Torino was damaged by a landslide. As a result, the transportation of goods had to deviate toward Vintimiglia in southern Liguria. Finally, in the summer of 2023, massive waves of mud damaged roads, cars, and buildings in Bardonecchia. As a result, the need for space devoted to data sharing between Italy and France has become urgent.

To understand the challenges of data sharing in this case study, we first identified the actors involved in DRR in the cross-border region. We relied on a literature review and interviews (see below) to list over 70 entities, 31 of which are Italian, 37 are French, 5 are international actors, and 5 are European. Most of these organizations involved in DRR are related to each other and form an ecosystem. Some of them are specialized in data related to natural hazards or resources (such as the Regional Agency for Environment of Liguria). Some others produce data related to the climate (such as Météo France or Copernicus) or territories (such as Open Street Map). Others, such as railway companies, are not specialists in data or DRR but could benefit from the data produced within the ecosystem to better prevent and prepare for disasters. While a data ecosystem could offer the opportunity for organizations to effectively share and use data for DRR, data sharing remains sporadic and local.Data collection

To address the research question, empirical data were collected primarily through archive analysis and semistructured interviews with experts and practitioners of DRR.

We examined the scholarly literature and archives concerning past cross-border DRR projects and existing data platforms and geoportals. We also searched for specific past projects related to DRR that took place at the Italy–France border and examined the archives of the Interreg program Alcotra. We also collected older archives about Italy–France cross-border cooperation.

Despite our focus on the Italy–France frontier, we also collected and analyzed data on other borders. We collected data on the Greece–Turkÿe border and the cross-border region formed by the Mekong River between Thailand, Lao, Cambodia, and Vietnam (Thu and Wehn, 2016). This helped us identify whether the challenges identified in our data related to the Italy–France border specifically or manifested in other cross-border regions as well.

We also conducted semi structured interviews by relying on a dictionary theme and an interviewer guide that we iteratively refined through data collection and analysis. During the interviews, we first asked the interviewees to present their work and contribution to DRR

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and resilience. We then asked questions about cooperation, data usage, and data sharing. The interviewees were contacted because they had developed diverse areas of expertise, ranging from territorial resilience, natural hazards, DRR, and cross-border cooperation. The interviewees were of various nationalities, including Italian, French, Greek, German, and Canadian.

By relying on the theme dictionary, we could adapt to the interviewee's expertise and her or his familiarity with data. Given the diversity of the data used for DRR and the exploratory nature of this work, we did not focus the interviews on the use of a specific type of data. During the interviews, we carefully avoided discussing critical events that might have impacted the interviewee emotionally. We also guaranteed the anonymity of the interviewee and her or his organization. No information was provided from the interviews to the organizations. After each interview, we used the snowball sampling technique to identify more interviewees. Finally, the interviewees helped us identify cross-border data sharing projects. Table 1 presents the interviews that we conducted and highlights the diversity of interviewees in terms of occupation, expertise, and nationality.

Approaching the topics of data and data sharing with the interviewees was a challenge in our study. Unsurprisingly, this stems from the exploratory dimension of this work. While experts may have a precise idea of the data needed for DRR (at borders), they do not always have an exhaustive view of the data practically used by organizations. Our difficulty in collecting precise and exhaustive data about data remains unsurprising. As documented, data are not trivial assets for organizations. Most of the time, data access remains confidential. Focusing on a specific type of data would have reduced the diversity of the interviewees and the explanatory power of the study. To address the difficulty of obtaining information about data from interviewees, we searched for datasets in 2023 that were accessible on the web also helped identify more specifically the type of data that we could mention during the interviews. From this search, we also identified the organizations that provided the data and contacted them. By doing so, we progressively improved the richness and relevance of the interviews.Data analysis

The collected data were analyzed by using MaxQDA. We followed the three steps of coding prescribed by grounded theory, which describes coding as an abstraction of data (Glaser and Strauss, 1967). Using this software, we first completed open coding. We identified some themes that composed the theme dictionary. We also identified other codes that emerged from the empirical data. For example, we identified the code "cross-border vision" that was not initially part of our theme dictionary. This code was then included in the last version of the theme dictionary and was systematically coded. We wrote memos about each qualitative code and discussed them within the team to enrich the codes. In the axial coding step, we coded the relationship between the codes and wrote memos about each connection that we identified. For example, the data suggest that the code "fragmentation" is related to the code "data literacy." We therefore coded "how fragmentation impedes data literacy." A premodel emerged from the analyzed data and was discussed within the team. Finally, we completed the selective coding, which helped us retain the code on the basis of a systematic comparison. In addition, dialogical reasoning within the team helped us check whether the model aligned with the data collected in the interviews.

We found several ways to support the reliability of our coding. First, we relied on dialogical reasoning to challenge each other's views

to refine our findings. Second, in April 2024, we presented these findings during a comodal workshop with both experts and operational actors. This opportunity allowed the findings of our study to be discussed and supported its refinement. Since then, the findings have been presented on a regular basis to practitioners and experts. In the future, they will be further refined according to further data collection and analysis.

Findings

This section provides a comprehensive account of the challenges to cross-border data sharing for DRR. In this account, we also demonstrate how DRR actors develop innovative practices on the basis of data itself to overcome these challenges. In short, the fragmentation that characterizes cross-border settings exacerbates (i) the lack of mutual trust, (ii) the lack of a unified data strategy, and (iii) the heterogeneity of data literacy across the border. To promote clarity in this work, the findings are structured in two main parts. The first part details the four challenges that the DRR actors face at the border, namely, fragmentation, the lack of a common view, and the lack of data literacy and trust. The second part of the findings outline the novel practices that have emerged from cross-border regions.

The border as a fragmented setting for DRR

We first explain in this section what fragmentation is and how it affects DRR. In this work, fragmentation refers to the divides, differences, and inconsistencies of views and practices of multiple stakeholders. Fragmentation manifests in technical inconsistencies (organizations using different standards) and the lack of operational joint procedures or standards between organizations. It also involves cultural divides and rivalries between organizations. Fragmentation affects DRR actors regardless of borders. As explained by a practitioner of DRR in France:

> "France is specific in that responsibilities are spread between various organizations. In France, these organizations do not communicate with each other. This means that organizations do not share their knowledge on risks in relation to a specific territory. This also means that no organization has a complete understanding of the risks. This electricity provider, for instance, focuses on the risks that are the most important to its functioning and relies on its own methodologies. The same for train transportation companies. The State manages national roads, and the issue is the same. Highways? The same. And so on. No exchange". [26_01_Op_07]

This quotation highlights how fragmentation affects DRR, even on the same side of a border. Two organizations might be interested in the same topic but never interact with each other. The lack of communication about methods and practices undermines the improvement of DRR practices in organizations.

Cross-border regions are naturally fragmented territories because they contain natural or artificial divisions (Kratke, 1999, Pawlak and Kurowska, 2012). Our point is that the challenge of DRR fragmentation is aggravated by the specific context of the border. While countries across

TABLE 1 List of the interviewees.

		Occupation	Duration	Date
1	16_01_Exp_01	Scholar in climatic geopolitics	44:28	16/01/23
2	02_03_Op_01	Civil protection commandant	01:13:15	02/03/23
3	28_02_Exp_04	Scholar in humanitarian studies	01:21:09	28/02/23
4	27_01_Exp_02	Humanitarian project manager	59:56	27/01/23
5	27_02_Exp_03	Chief officer of a project on resilience and critical infrastructures	01:04:10	27/02/23
6	23_06_Op_02	Emergency manager	37:38	23/06/23
7	10_07_Op_05	Emergency manager	01:27:32	10/07/23
8	27_06_Exp_07	Scholar in geography, risks, and data	44:38	27/06/23
9	03_07_Op_04	Firefighter captain	42:54	03/07/23
10	29_06_Exp_08	Scholar in geography, risks, and data	01:03:20	29/06/23
11	16_08_Op_06	Emergency manager	01:03:00	16/08/23
12	23_06_Op_03	Prefectural decision-maker	51:03	23/06/23
13	29_12_Exp_09	Former manager of cross-border projects	50:00	29/12/23
14	04_01_Exp_10	Director of natural risks prevention unit	01:32:38	04/01/24
15	18_01_Exp_11	Territorial cohesion advisor	49:09	18/01/24
16	26_01_Op_07	Chief officer of a service devoted to risks and territories	01:26:13	26/01/24
17	02_02_Op_08	Emergency manager	01:17:43	02/02/24
18	05_02_Exp_12	Natural risk expert	01:16:12	05/02/24
19	05_02_Exp_13	Scholar in cross-border resilience	01:29:15	05/02/24
20	06_02_Exp_14	Chief officer of a service devoted to natural risks	01:06:05	06/02/24
21	06_02_Exp_15	Scholar in cross-border cooperation	01:31:46	06/02/24
22	13_03_Exp_06	Scholar in climate change response strategies	01:00:13	13/03/23
23	10_03_Exp_05	Scholar in international humanitarian law	59:21	10/03/23
24	14_02_Exp_16	Director of nonprofit organization	45:00	14/02/24
25	10_06_Op_09	Chief officer of a service devoted to risks and territories	01:21:00	10/06/24
26	17_07_Exp_17	Associate professor and director of a research center	01:01:43	17/07/24
27	24_09_Op_10	Director of a non-profit organization	46:44	05/09/24
28	18_07_Exp_18	Research director	01:33:10	18/07/24
29	13_09_Exp_19	Expert on data ecosystems and data spaces	48:33	13/09/24
30	05_09_Exp_20	Expert on cross-border cooperation	01:03:01	05/09/24

borders do share common risks, there is often a lack of coordination and communication between them, leading to a disconnected approach to risks related to disasters. The case of Italy and France illustrates this point well. As the events in Bardonecchia reveal, disasters involve cascading effects from one side of the border to the other. However, the two countries approach risks related to disasters in different ways. Italy has been strongly vigilant regarding volcanic activity and earthquakes. In contrast, in France, much attention has been given to floods. As a result, Italian and French cross-border regions struggle to develop a common risk and DRR strategy.

In fact, cross-border territories are persistently perceived as lines of separation rather than liminal spaces. As a result, despite the collaborative efforts documented here, cross-border DRR actors tend to focus on local issues that expand to the topological limits of a country. An expert on the Italy–France border explained that the Alps remain a frontier between two territories rather than a single shared territory. Fragmentation between Italy and France also induces some semantic inconsistencies

between them, which prevents DRR actors from knowing each other well. As explained by an expert on cross-border cooperation, the use of distinct terms between countries to designate the same object prevents cross-border DRR actors from developing a shared lexicon:

> *"At borders, there might be some confusion regarding the terms "civil protection" and "civil safety", with or without armed forces. Other European countries, on the contrary to France, do not use armed forces for civil matters at first intention".* [Exp_01]

Lacking a clear understanding of what civil protection consists of is not only a semantic issue. The discussion outlines the lack of clarity regarding which organizations participate in DRR in each country. This lack of clarity prevents the rise of a unified representation of DRR and its actors. Furthermore, fragmentation induces a lack of knowledge about the methods and resources employed by DRR actors across borders. As explained by an official who used to work in a French

prefecture at the border, French and Italian organizations do not always know about each other or about the data and methodology employed.

In the remainder of this section, we explain how fragmentation complicates the settling of a unified data strategy for DRR actors, thereby preventing data sharing for DRR at borders. More precisely, rivalries nurture mutual defiance and undermine trust in data sharing across borders. As a result, cross-border actors develop heterogeneous levels of knowledge about data and its use, which in turn undermines the development of data sharing for DRR.

Lack of mutual trust

Fragmentation at borders can be fueled by the legacy of past conflicts. This means that fragmentation is not only about operational inconsistencies but also comprises persisting disputes and rivalries, possibly about data. With respect to DRR, the interviewees highlighted the ambivalent status of data in a border setting. On the one hand, data represent valuable resources that can be used to collaborate on risks because, as mentioned earlier, one single organization (or country) cannot produce on its own all the data necessary to predict disasters. On the other hand, data are also sources of power and, according to some DRR actors, should be retained. As explained by an interviewee:

> *"Data is information about something that happened or might happen and it's controlling narratives. (…) So, it's about the narrative [produced out of data] and the data more than the technicality of how to share data. The other part that is more technical, but it's not just technicalities (…). Although it's a narrative, it doesn't talk for itself and that's what a lot of actors are really afraid about sharing data because if you don't know the context in which the data was collected, for which purposes, you can quite easily misuse it or misunderstand it, and it's almost super difficult to explain all the context. (…) [Data's] power is narrative (…) it doesn't tell the whole story".* [28_02_Exp_04]

Trust in data sharing remains fragile at borders. In addition to persistent sources of defiance related to politics and the legacy of conflict, data can be perceived as a major threat. DRR actors need to overcome these challenges, which complicate cooperation and data sharing.

Lack of a unified data strategy for DRR

Fragmentation implies the use of different technologies and tools, sometimes with the same data, in a way that does not allow seamless integration between DRR actors. An interviewee with significant experience in DRR at an international level explained that DRR actors have difficulty understanding a specific situation across borders because their methods and tools lead them to disparate results:

> *"The problem is that maybe the risk that they're seeing in Brussels based on the data they're looking at is not the same at the risk they're seeing maybe in Croatia with the data they're looking at (…) and a reason behind that is because they're not using the same platform. They're not using the same algorithm. They're not using the same way to predict risk. And so it doesn't matter if you share data. So the*

> *Croatians can share the data to the Brussels, but then they said, okay, this is not what I have. The Croatians might think they're correct. They might think, no, they think they're correct. And Brussels, they also think they're correct, but because they're looking at different data or they're looking at the same data differently"* [24_09_Op_10].

As this quote illustrates, fragmentation implies divergences in the way DRR actors process data, both from a technical perspective (formats, metadata needed, means of storing the data) and from an organizational perspective (how to use the data, methods to process, visualize, or even transmit the data). As a result, they develop siloed approaches to data that prevent the coconstruction of a unified cross-border strategy that can support data sharing.

Unequal levels of data literacy

Data literacy is the ability to understand, find, collect, interpret, visualize, and support arguments using quantitative and qualitative data (Wolff et al., 2016). Data literacy includes the ability to formulate and answer questions using data as part of evidence-based thinking. It also involves using appropriate data, tools, and representations to support this thinking: interpreting information from data; developing and evaluating data-based conclusions and explanations; and using data to solve real-world problems and communicate their solutions (Vahey et al., 2012).

Across the Italy–France border, organizations have developed divergent levels of knowledge on data usage. While some Italian organizations might be accustomed to implementing APIs, their French counterparts may still struggle to analyze their own data. As witnessed by a data and DRR expert with significant experience at the Italy–France border,

> *"We updated a database of natural risks from a National Observatory of Major Risks. We completely overhauled the site in an attempt to work interoperably with the Italians, but we were caught up in time and major problems with our IT service provider, and we didn't get to the end of what we wanted to do in terms of interoperability, as explained by an expert of border resilience"* [10_06_Op_09].

The divergence of experience in developing interoperable tools involves asymmetry of knowledge about data across borders and across organizations. As explained by an emergency response director,

> *"I think it's a question of knowledge and information, of being well aware which type of data, how many different data, what means strategic data or operational data… I think, at the end of the day, what we have is a lack of knowledge, of how to handle data".* [14_02_Exp16]

The asymmetry of knowledge prevents the rise of shared rationales or agreements to share data. When data are collected without any perspective on their usage on one side of the border, organizations can struggle to promote data sharing. A practitioner of DRR and crisis response explains some interactions with foreign counterparts who do not understand the benefit of sharing data:

"Because they think information is power, but information is out there. I mean, I remember once I asked for information about a forest fire. And they said "No, no, no, we cannot give you information about this" Okay. Can you guys tell me the date of this fire? Sure. I said, everything is public. I mean, look, I can show you the perimeter. I can show you the weather conditions of that fire that happened three years ago. It's out there. So, it's so stupid now to keep the information just for you because it's out there. I mean, what's the point? Maybe a hundred years ago. Yeah. Information was powered, but now it's out there. You just need to learn how to seek that information. So, for me, it's so stupid to try to keep the information just for me and not share. I'm not going to share with you. What's the point? Because it's out there." [24_09_Op_10]

As a result, differences in skills and proficiency in data usage, in addition to siloed views on data, led to significantly varying levels of data literacy among the DRR actors. In sum, the findings highlight three major challenges exacerbated by fragmentation at borders, namely, lack of mutual trust, lack of unified data strategy, and unequal levels of data literacy. Despite diverse impediments to data sharing among DRR actors at borders, empirical data help provide a more nuanced view of data sharing for DRR at the Italy–France border. Progressively, DRR actors have been searching for practical ways to facilitate collaboration on data and data sharing. In both bottom-up and top-down methods, a shared vision of DRR has emerged, and both sides have been progressively converging on common grounds in relation to data and DRR.

Search for collaboration on data at multiple levels (European and local)

For decades, some local DRR actors have been working to create practical tools and solutions to share data across borders, such as Amis and ConcertEau. In line with this effort, some DRR actors have increasingly developed their awareness of the need for data integration and collaboration across the border. Most interviewees converge on the need for a single point of access to data that would foster information integration and standardized practices related to data for DRR. As explained by a European DRR practitioner:

"We have a huge dispersion in the state of things today, especially in France (…) maybe I'm wrong, but I have this impression all the same information service providers, particularly in the field of natural hazards, are multiplying and working in parallel. So, on the one hand, I think all this is interesting, because it means there's a multiplicity of approaches, interesting contributions, and so on. But at some point, to manage a crisis, everything has to be, has to be concentrated in a single tool. And so, if you have this study activity on a portal that can be of service, the first thing of this portal is to make sure to concentrate all the information that comes from a constellation of suppliers in order to validate it, if necessary, but in any case, to have a vision of the situation". [18_07_Exp_18]

This quote first reveals that data integration is unequal across European countries. Additionally, it accounts for the richness that stems from the diversity of initiatives and views on data. This richness, however, requires the integration and use of a unique tool across borders. The DRR actors are also aware of the need for thorough discussion between them to build a unified view of the data for DRR.

"So somehow we need to agree what are, what is, what we need from that data? What do we need from it? How are we going to achieve that? And what is the data that we need to put into this new organization to come out with this product in a harmonious way. I think that can fit. I mean, it's going to be, that's going to be a big, big challenge because putting together 27 member states is going to be terrible. But it's something that we need to do. That is something that we need to do if we want to improve and enhance risk prevention. And if we want to enhance coordination among the member states when it comes to emergency management. So. But it's a big, big challenge". [18_07_Exp_18]

At the European level, DRR actors are becoming aware that the coconstruction of a new data strategy can help gain insights into each other's roles and contributions, as well as support DRR. At the local level, the proactive search for data collaboration is not merely a claim made by the interviewees. Despite silos and fragmentation, organizations have been establishing local networks associated with specific territories. Italian and French DRR actors recognize the potential of data produced by other organizations and the possibility of sharing it.

In particular, DRR actors nurture coconstruction between organizations that share diverse types of expertise. As explained by an expert who has been frequently involved in resilience projects, coconstructing solutions to address disaster-related risks appears very beneficial. The coconstruction of solutions implies repeated interactions that provide the opportunity for DRR actors to understand each other's roles and values well:

"[Organizations] rely on us because we have some expertise and some data to bring. We bring technical expertise to them. When we deliver this expertise, it is clear that we increasingly coconstruct the final product or service [with these organizations]. This is the way it is. Coconstructing things is a way for us to be sure that we will address the demands [from organizations]. It is a way to well understand what [organizations] need and to be sure that we well address needs and to understand how our services can be used for what action afterwards". [26_01_Op_07]

As the quotes reveal, collaborative efforts are both planned and emergent. They primarily concern DRR actors from the same side of a border. However, in addition to the promotion of cross-border data sharing by European institutions (through Interreg projects and ECHO funding), local DRR actors have been developing bilateral cooperative ties to learn how to share data with each other. As explained above,

"Our work involves a lot of interaction about what we're doing, what they're doing, what's working, and so on. We also share data, we share methods, we apply each other's methods. We also drew up a document called Strategic Document on Risk Communication This document is online and of how risks in the Alps are communicated in France and Italy". [10_06_Op_09]

Such efforts support the sharing of data, even though they remain local and bilateral. About a cross-border data platform, a DRR actor provided the following explanation:

"We really showed on (our) (web)site that (the platforms) is designed for working on both scales in both countries. On the Italian side, it has enabled them to go further on in the Piedmont region, where they can display and visualize French data". [10_06_Op_09]

Building trust and inclusivity

This section explains how cross-border DRR actors work to establish mutual trust and inclusivity to facilitate data sharing. First, many of the practitioners interviewed identify trust as a significant factor in enabling cross-border collaboration and data sharing. Cross-border cooperation (especially in relation to data) requires dynamic and continuous engagement from all parties involved. As explained by a project manager involved in multiple DRR projects, trust is a targeted prerequisite for cooperation in data.

"Fundamentally, this is what we look for, trust, as it is essential to cooperation, which itself is essential in order to solve these problems". [18_01_Exp_11]

How can trust be built? First the DRR actors proactively handle misunderstandings and other threats to the trust established with their partners, which demonstrates their commitment to nurture collaborative and transparent connections:

"If they need us, they have to trust us, and if we want to work to help some other partners (…), we need to believe in it (…). And if we think that there is no trust, I think we should rather put the matter on the table and tackle it or clarify our intervention". [26_01_Op_07]

Second, DRR actors work on bridging language to build mutual understanding:

"Language is really the most important thing, even if there are translators to negotiate things, to set up projects, to get along even when you do not agree, and so on. When I started speaking Italian, I was considered a bit more. And I think it's more normal because they make the effort to speak French." [26_01_Op_07]

Third, the DRR actor's search does not amount to only nurturing trustful interactions but also consists of updating their own infrastructures. Many interviewees, while acknowledging the potential challenges associated with data, adopt a transparent and collaborative approach to data sharing at borders. As explained by a DRR expert,

"So, in principle, based on what I see, everything is shareable. I can share everything. Ah, one issue, perhaps, now that you, I think of, is whether you will share a flood probability with the common public, with the public. This is an issue here because of the potential of creating stress to the population, let's say, so that the people will not get afraid of what's going on. So, there will be an orderly, if you like, even evacuation of some areas. So, this could be something that can be considered, whether all this detailed information could be shared with the public, the public. However, having said that, there are lots of open websites nowadays that also develop and produce this information. So, it's not like even if the

government decides, okay, I'm not going to show you all the details that the citizens cannot find from somewhere else. So, again, perhaps this, but probably not. Probably everything can be shared by everyone. With what process is another issue".

Fourth, inclusivity is important. Disasters primarily affect citizens. Additionally, citizens are important stakeholders of data sovereignty. Considering the combined stakes of resilience and data sovereignty, citizens expect data transparency and need to work closely with institutions. As outlined in the previous statement, citizens can manage to find a large amount of data and information on their own, which calls for their inclusion in data sharing for DRR. As explained by an expert in cross-border cooperation, the inclusion of citizen who share the same cross-border territory drives cross-border cooperation:

"The (…) idea, which is fundamental given that we are in the same geographical area, is interdependence. And for me, interdependence requires fraternity, which for me is a component of citizenship. We need to get back to basics. Basically, a community of destinies is someone who assumes fraternity or solidarity while respecting diversity, because it is in the service of a common good: the protection of services and goods. So that's the fundamental thing we're looking for. If you don't have that sense, there's no point" [24_09_Op_10]

This quote highlights DRR actors' awareness of the important role of citizens in DRR and resilience. In line with this view, future citizens need to learn how to process data from sources abroad and understand the conditions for their production:

"When it comes to public data, I've never seen any reticence or opposition to sharing data. The problem, as I mentioned earlier, is the ability to compare these data. This requires us to see how each piece of data was produced. And how it is produced requires a good knowledge of each country's internal systems. Then there is the question of the reliability of the data. (…) As a very sensitive European citizen, I'm very cautious about this issue for future generations. I'm fighting for European digital sovereignty, but it's an uphill battle". [24_09_Op_10]

Discussion

Although data sharing at borders does not yet appear to be fully effective at multiple borders, it remains an important driver of DRR. However, the nature of the challenges in data sharing for DRR at borders remains only partially understood. For this reason, this research addresses the following research question: *"What are the challenges of cross-border data sharing for DRR, and how can DRR actors address them?"*

Our empirical findings highlight fragmentation as a core challenge to data sharing across borders. More specifically, fragmentation can prevent DRR actors from building mutual trust, developing a unified data strategy, and converging on a common level of data literacy. However, DRR actors are adapting their practices to address these challenges by seeking collaboration and fostering trusting and inclusive relationships at the local level. We discuss in the following lines the theoretical contribution of this work and its practical implications.

Theoretical insights

Our findings highlight the importance of fragmentation in the Italy–France cross-border region. Previous research has highlighted that fragmentation hinders cooperation across borders. Fragmentation has been less frequently addressed in the context of DRR but has been attracting scholarly attention increasingly (Koukis et al., 2016; Migliorini et al., 2019; Rivera et al., 2015; Wisner et al., 2011). Research on this topic advocates comprehensive and sociotechnical approaches to DRR and borders (Adrot et al., 2018; Petrenj et al., 2013).

To date, the literature has outlined how data sharing at borders confronts a lack of interoperability and divergent vocabularies, norms, and equipment (Liverani et al., 2018). Fragmentation can undermine information sharing and communication (Rivera et al., 2015) and data sharing, even across borders. The above literature seems to lead to the pessimistic conclusion that data sharing for DRR at borders is an impossible mission. For the sake of cross-border resilience, providing a comprehensive explanation of the nature of the challenges facing data sharing for DRR at borders is important.

This is what this study proposes to do. It explains how fragmentation can be exacerbated in cross-border settings. Fragmentation at borders undermines trust, the data strategy and the convergence of data literacy across borders. Moreover, the challenges of cross-border data sharing for DRR are not static. In contrast, our analysis reveals that DRR actors have been making significant efforts to overcome these challenges. In doing so, they have been adapting from situations where data cooperation is at stake but still in its infancy.

In other words, data sharing at borders cannot merely be designed and planned, given the problem of fragmentation. DRR actors also need space to experiment with cooperation, trust, and inclusion. Emergence represents a fragile but essential avenue to cross-border data cooperation for DRR. From this perspective, this work contributes to the understanding of cross-border data sharing for DRR by highlighting the role of emergent and adaptive practices related to trust, data literacy and inclusivity.

As a limitation, our research cannot conclude whether emergent and adaptive practices are sufficient to achieve higher levels of data integration. However, they provide a more nuanced and dynamic view of data sharing for DRR at borders. The findings also highlight the role of agency in such settings.

From our comprehensive stance, trust emerges as a first-order condition of the emergence of cross-border data sharing. Our findings show that DRR actors primarily work on trust to support data sharing. This view echoes existing research on cross-border cooperation (Koch, 2018) and suggests the need to help DRR actors build mutual across borders in parallel to data related technology implementation at borders.

More specifically, cross-border communication involves not only the absence of defiance but also a proactive and somewhat asymmetrical commitment (Zaheer and Zaheer, 2006) to transparency, mutual accountability, and collaborative engagement. The process of trust building, as an iterative process, is particularly critical in contexts where past conflicts and competitive tendencies prevail (Koukis et al., 2016). In line with this view, our analysis reveals that data sharing for DRR across borders is both dependent on and an enabler of trust. However, the fueling of mutual trust between local DRR actors also requires continuous efforts to align data standards and practices. In sum, the pursue for data sharing for DRR at borders relies on a thorough socio-technical and emergent process, during which DRR actors altogether experiment integrative and inclusive initiatives related to data.

Practical implications

Our research highlights the importance of practical and collaborative efforts to build trust between actors. These efforts are emergent and cannot be designed solely in a top-down fashion. More specifically, our findings suggest the complementarity between top-down and bottom-up approaches to data sharing across borders. The top-down approach was described in the Italian French case as essential for funding projects and initiating collaborative projects at the European level. However, the top-down approach alone cannot overcome the effects of fragmentation on data sharing. A bottom-up approach to data sharing for DRR can promote inclusive and practical leadership in data sharing but also requires institutional support and guidance.

Our research also suggests that cross-border DRR actors can overcome fragmentation and the lack of trust through emergent and local cooperation. This implies that the projects, protocols and resources for DRR elaborated in a top-down fashion must be flexible enough to local DRR actors. The projects, protocols and resources to promote data sharing for DRR may exacerbate the fragmentation of views on data or, if appropriated and enacted by local DRR actors, can contribute to a unified vision of data sharing. While the literature advocates the creation of ecosystems to facilitate data sharing (European Commission, Joint Research Centre, 2021), we highlight the limitations of "by-the-book" solutions to achieve this. Adopting frameworks and tools without considering the features of the cross-border region hosting the ecosystem can be misleading. As evidenced by the analyzed data, DRR actors at borders need to jointly construct a specific vision of DRR and data that might remain unstandardized.

Conclusion

This research aims to provide a comprehensive understanding of the challenges of data sharing for DRR at borders. On the basis of a qualitative research design, this study examines the case of Italian and French data sharing for DRR at the border. The findings highlight how the context of borders interacts with the inherent challenges of DRR. As a result of this interaction, DRR actors struggle with a lack of mutual trust, the absence of a unified data strategy and uneven levels of data literacy. However, DRR actors address these challenges in an unplanned and emergent fashion. Through their interactions, they struggle to foster trusting and align their data practices. They promote inclusive relationships and proactively seek collaboration. These findings outline the emergent side of data sharing even at borders, one of the most fragmented settings. In line with this view, local DRR actors' appropriation of top-down resources and protocols for data sharing and DRR is crucial.

Data availability statement

Author contributions

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Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. Deepl Pro was used to verify and correct the grammar of some sentences.

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